





CAYLEY (Sir George). <sup>With note in Cayley's written  
all back</sup>  
Practical Remarks on Aerial ~~RAMP~~

Navigation (Reprinted from the "Mechanics  
Magazine", No 708, Sat. Mar. 4, 1837).

with: (ibid.) Description of an Artificial  
Hand, '845.

and: (ibid.) Essay on ... Promoting Safety  
in Railway Carriages.

443 3 pamphlets by Cayley in 1 vol, 8vo  $\frac{1}{4}$  cf. v. 4.





































Yours truly  
George Cayley

*Engraved by J. P. Newton from a daguerotype portrait by Beard.*



# DESCRIPTION

OF AN

# ARTIFICIAL HAND.

BY

SIR GEORGE CAYLEY, BART.

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[REPRINTED FROM THE "MECHANICS' MAGAZINE" FOR MARCH, 1845.]

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LONDON:

TYLER AND REED, 5, BOLT-COURT, FLEET-STREET.

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1845.





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INSCRIBED

TO HIS HIGHLY VALUED FRIEND,

PETER MARK ROGET, M.D.,

SECRETARY OF THE ROYAL SOCIETY, VICE PRESIDENT OF THE SOCIETY OF ARTS, &c.

BY

THE AUTHOR.



DESCRIPTION  
OF  
AN ARTIFICIAL HAND.

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20, Hertford-street, March 5th, 1845.

SIR,—About eight years ago, George Douseland, a son of a tenant of mine, had the misfortune to lose his right hand, when I proposed to make him an artificial one, in the hope of rendering his loss rather less severe. The greater portion of this instrument was made, and the whole of it planned, at that time; but the stump was found to be so tender that it could not then be made use of, if completed; and the young man having gone to reside elsewhere, the thing was lost sight of, and was not renewed till about two months ago, when the remaining portion was executed; and he has found it of considerable use to him in his various daily occupations. I send you a sketch and description of this instrument, which is so simple, as scarcely to deserve the name of an invention; but trusting that it may be found equally useful to others under a similar misfortune, I wish to give it to the mechanical public through your valuable pages.

The instrument can be executed in many ways, though the means of deriving its firm and forcible grasp from the stump must remain much the same in all. Flexible tendons were adopted in the first sketch I made of this instrument, but I shall describe that which is now in use, and subsequently some very essential improvements. I hope by thus publishing it to prevent its being pirated and *patented*, as it is quite misfortune enough to lose a hand, without being obliged to forego the use of even so humble a substitute, for want of means to purchase it, or otherwise to procure it at an exorbitant price.

I am, Sir,

Your obliged and obedient Servant,

GEORGE CAYLEY.

*Method of making an Artificial Hand, that will forcibly grasp substances of various sizes, and release them at will, so as considerably to supply the place of the natural hand, when that member is lost.*

The movements of this instrument are derived from the stump, by fixing the hand to the upper portion of the arm above the elbow joint, by light frame work, within which the stump has its movements at full liberty; and by placing a shank or lever, connected with the machinery of the hand, to the termination of the stump, it is put into forcible and efficient use.

This will be more clearly understood by inspecting the sketch fig. 1, where A A represent metallic half hoops, riveted to the thin steel bars B B, and padded on the inside. When the arm is placed in these semi-hoops, it is secured there by the straps and buckles C C. The end of the stump is at the same time inserted into the padded hoop D, riveted on to the bars E E, which turn freely on the joints F F.

The hand, fig. 2, is fixed to a hoop G, which fits freely into the hoop H, fig. 1, at the termination of the arm bars K K, and can turn within it, but cannot escape from it, by means of three small screws working in a groove.

The joints F F are common to all these bars; but the bars K K can be fixed in any required position by a sliding spring bolt, working into teeth or holes in a circular part of the upper bar B; hence the horizontal pin, M, is made to move up and down by the muscular motion of the stump, although the hand remains stationary.

Fig. 1.

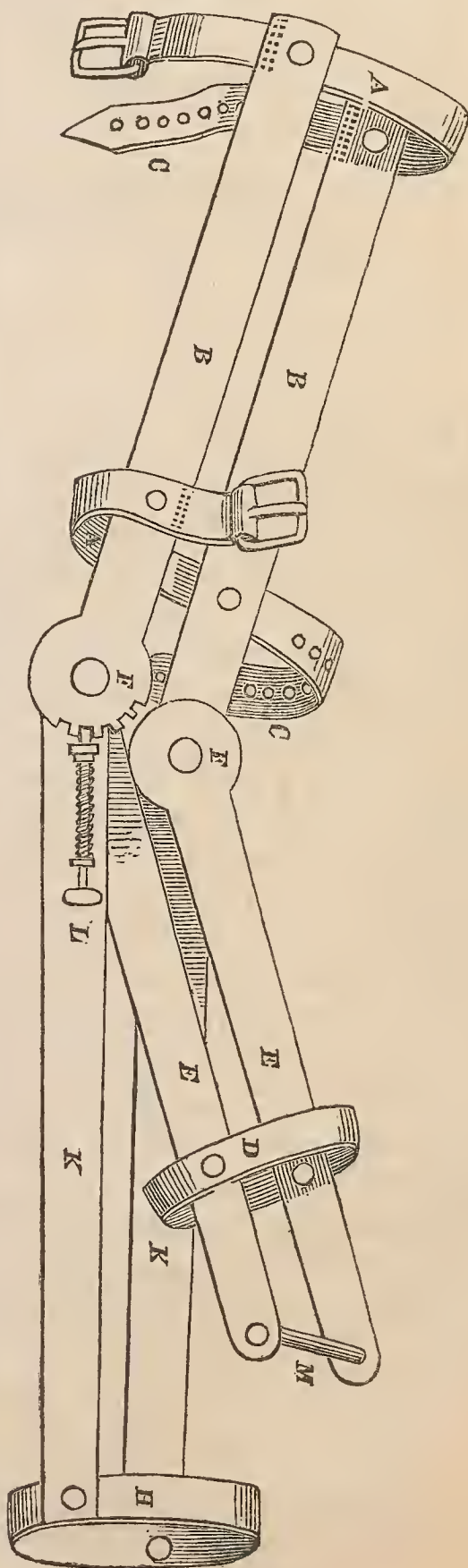
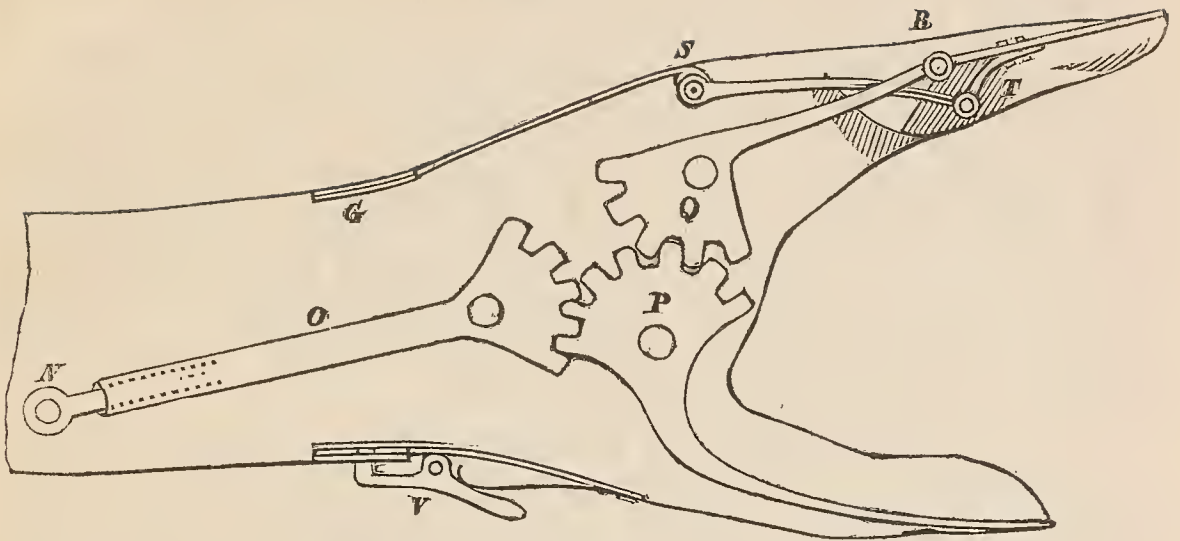




Fig. 2.

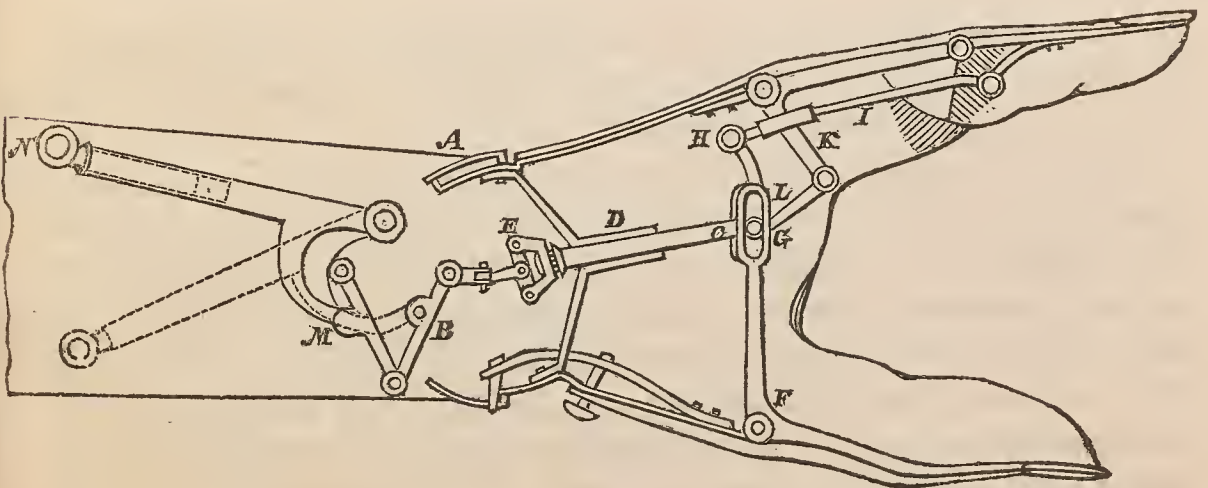


This pin M is inserted through the eye or loop N, fig. 2, the shank of which slides in the tubular lever O, carrying an arch head, with teeth, and thus moving similar arch heads, P and Q, in opposite directions, the slender shanks of which form, when packed with cork, or other light but firm material, and covered with leather, the thumb and fingers of the hand.

A second and more rapid motion is given to the fingers at R, fig. 2, by means of a thin rod, or steel tendon, commencing at a stationary joint, S, terminating in a second joint or eye, T, and perforating the finger rod near its outer joint.

The whole hand can be twisted round into several positions by the ring on which it is fixed revolving within the outer ring attached to the upper arms; and it is retained in these positions by means of holes, through which a spring catch plays, as seen at V, fig. 2.

Fig. 3.



There are two considerable deficiencies in this construction ; first, that the hand cannot be turned even so much as a quarter of a circle from its horizontal towards a perpendicular grasp ; secondly, that there is no movement equivalent to the usual bending of the wrist, which gives so great a variety of positions to the natural hand ; indeed, it is not obvious, at first sight, how any other than an horizontal grasp can be given by this instrument, the movement of the pin M being horizontal, and parallel to itself. When, however, the hand is turned up to effect a perpendicular grasp, the action of this pin is oblique to the eye N, which then slides along it, and thus communicates its movement to the hand, full as forcibly as when it is in the horizontal position.

To obviate these defects, let the wrist A, fig 3, be constructed with a hollow ball and socket movement, or other equivalent contrivance, having a range of about the eighth part of a circle ; and let this be held fast at any required point by a spring catch as before, falling into a hole in the stationary portion, which must be drilled like a sieve, to suit every position. To the inner or moveable portion the hand is fixed ; and the movements of the fingers and thumb are communicated from the eye N, through a small rod B, turning on a hinge, and from thence, through a connecting-rod carrying universal joints at both ends, to a cylindrical rod, C. This rod slides freely in the tube D, and can permit one of these universal joints, E, to turn freely in a groove round it. The motion of the thumb piece F, which here, as in nature, is slower than that of the fingers, is derived from the centre pin of the joint G, passing through a slit or elongated eye in a rod hinged at the bottom, and on its prolongation above, carrying an eye, forming the joint H, from whence the steel tendon, I, gives the second movement to the fingers as before. The bent finger-piece is also coupled with the end of the rod C by a short connecting piece, L. In some cases the rod B, which elongates the movement, may be dispensed with, and the universal joint E be connected directly with the joint M.

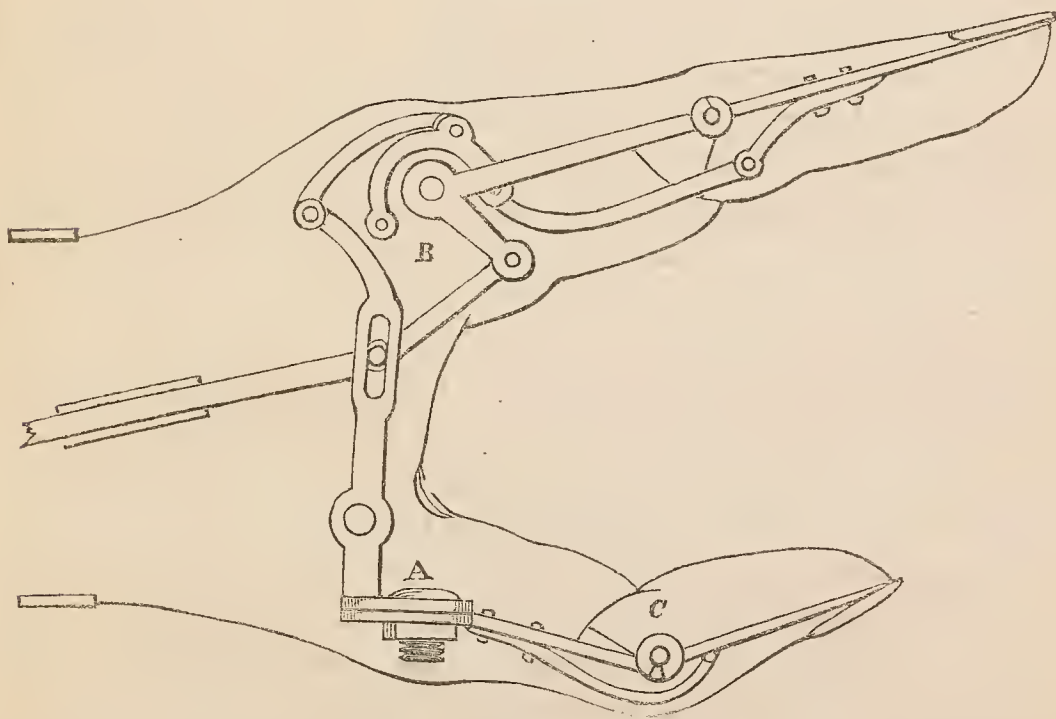
It is evident, from this construction, that the grasp will be equally firm in whatever position the hand be placed, either as it respects the bending of the wrist, or its rotatory movement.

In the structures before described a pressure or grasp between the thumb and fingers near their extremities is effected, and also the holding of substances of a moderate size near the middle of the hand ; and perhaps this may in most cases be as much as is required where the person employing it has only lost one hand, and can therefore do any more difficult task with the other ; but there are persons who have had the misfortune to lose both hands, in which case it is desirable to give this substitute all the efficient movements it is capable of. With this view, let the thumb piece,



as at A, fig. 4, be furnished with a horizontal joint capable of being screwed firmly against a spring plate, so as to create sufficient friction to prevent its turning with inconvenient freedom, (any required position may also be secured by a spring catch or detent.) By means of this joint the thumb can at any time be turned, as in the natural hand, out of the way of the grasp of the fingers, so that these may close round till they meet the ball of the thumb. This will enable many things to be held more conveniently and firmly than when the thumb meets the extended fingers at some intermediate point, and stops their further progress. To effect this greater range of the joints of the fingers, some little adjustment of the former plan is required. It may be effected many ways, but let the arrangement shown at B, fig. 4, suffice for the present to explain what is intended. And these movements being chiefly similar to those in fig. 3, will readily be understood, without further explanation, by reference to that figure. George Douseland can write, though with difficulty, with the hand as constructed in fig. 2, but an inventive young friend of mine\* has suggested the use of a spring movement in the last joint of the thumb, as at C, fig. 4, which will enable the pen to obey the pressure of the fingers

Fig. 4.



backward in the down strokes; and to propel it forward in the up ones, as the fingers relax their force. This light elasticity of the thumb ceases when pressed back to its natural position by the joint being made incapable of receding further; and, hence, it will be no detriment to the firm grasp between it and the fingers.

\* Edward Stillingfleet Cayley, Esq., Jun., Trin. Coll., Cambridge.

To avoid confusion in the figures they are drawn so as to show the movement of one finger only ; and in the hand worn by George Douseland there is but one such movement, all the cork fingers being united side by side, and fixed to one broad thin steel plate, jointed, as shown in fig. 2, and covered with continuous leather, only stitched down to mark the distinction of the fingers under it. For common use in most cases this will be sufficient ; but where a more expensive apparatus can be afforded, and the appearance of having a real hand is an object, this thin steel plate can be separated into digits, though united at the base and jointed at the proper places in due proportion to each finger ; and the tendons piercing these plates may be either hinged to fixed joints, as at S, fig. 2, or worked from a horizontal extension of the joint H, fig. 3.

All the required movements can be effected by catgut or other tendons attached to the joints of the fingers, as in the natural hand, and terminating in loops or eyes, on different parts of such a hinged bar as F H, fig. 3, so as to give them different ranges of tension to suit their respective purposes. This structure implies the necessity of a counteracting worm, or other spring movement, to extend the fingers and thumb again. Very light and elegant hands may be made on this plan, which would be suitable for the fair sex, and for light work. I before said, the first drawing made of the hand for George Douseland was on this plan ; but I found that he could lift the weight of five stone with the stump, and that the strength, precision, and durability of steel joints and tendons were more suitable to his work. These have also the great advantage of giving both extension and contraction with no counteracting spring to weaken the effect. By one simple, lasting, and efficient means, both these actions are produced with perfect precision in all weathers.

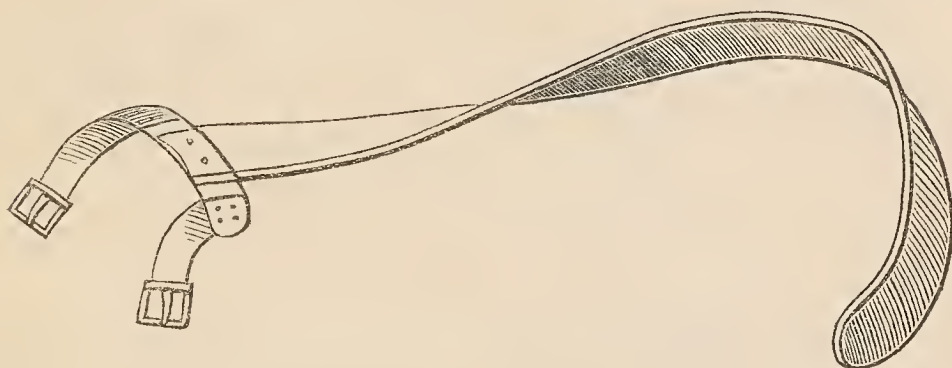
This instrument, in all its forms, has only been represented as working when the spring bolt L, fig. 1, secured the lower arm from turning on the hinge F ; but conceive this spring bolt occasionally drawn back, and secured from acting ; and that a spring friction plate held the joint F from turning, with less than three stone weight applied at the ring D by the stump ; the grasp of the hand could then be used only up to that extent of pressure, sufficient, say, for example, to lift a can full of liquid ; thus, if more than three stone force be applied, the friction of the joint will be overcome, the can will still be retained with the same power, but the movement of the joint will allow it to be lifted to the mouth. This is only one example of a very important principle, applicable to innumerable instances, and which greatly increases the use of the apparatus.

The same principle may be carried out to a still greater extent in respect to convenient use, though not perhaps with so much power, by supplying the action of a strong spring in lieu of the friction plate. Let this spring



be so arranged as to keep a nearly equal tension or pressure to retain the rods B, and K, of the upper and lower arms, in a right line with each other, and to restore them to that position whenever the elbow joint is bent. By this means, supposing a glass, a spoon, or other matter of light grasp be lifted to the mouth, as before described, it will not then be necessary to take it away from that position with the other hand, as when the friction plate is used, for the reaction of the spring will continue the grasp, as the arm unbends by the downward movement of the stump.

Fig. 5.



One necessary aid to this instrument in all its forms is, to give support to its weight from the neck and shoulder; which, in the case of George Douseland, is effected by a padded flat iron hook, surrounding a considerable portion of the neck, under the collar of the waistcoat, and passing behind it, so as to terminate on the shoulder, where it is cupped a little, to give it firmness of seat. To this part the upper ring A of fig. 1 is attached by a couple of straps with buckles,—see fig. 5. By this means, the arm is not fatigued by the weight of the apparatus, and the joint F is at all times preserved in the same line of axis as that of the elbow joint, with which it has to move as on a centre common to both.

As the hollow ball and socket movement, previously suggested, will require very excellent workmanship to render it efficient, it will be as well here to remark, that with much coarser work the wrist movement may be effected by an external hoop, similar to H, fig. 1, containing a second, that can turn completely round freely within it, but confined from escaping by any of the usual means. The inside of this hoop should be cupped, so as to approach a section of the globular form; and a third hoop, externally, a similar segment of a globe, but a size smaller, must fit, without much nicety of adjustment, within the second. An axis passing through the centre of both these spherical portions is fixed to the inner one, but turns freely in a collar in the second, the end being flush with its exterior surface. The ball and socket action, so far as it is used, is here derived from the one turning on an *axis* within the other, and not from the accurate

fitting of these spherical portions. Any required position of the hand, which is attached to the inner ring, can be secured by a catch and holes to receive it as before. On the centre of this axis the tube D, fig. 3, may be fixed.

I am sorry to give you so many dry details, of no interest excepting to workmen, to whom, in fact, this communication is chiefly addressed, and without whose aid those who require the use of this instrument cannot procure it.

A much more simple and less costly hand than that worn by George Douseland, at the Polytechnic Institution, might be made, chiefly of wood or bone, for poor persons; and I hope, that all good workmen, who live by the use of their own hands, will, when called upon to make these humble substitutes for the poor man's *capital*, (for so, in fact, the hand is to him,) exercise a generous sympathy towards the sufferer.

G. C.

P.S.—Since the publication of this article in the “Mechanics’ Magazine,” Mr. Buckingham, of the Colonnade, Grenville-street, Brunswick-square, has practically carried out, in the most expert and ingenious manner, and with several modifications of his own, all the movements of the artificial hand here suggested.

# PRACTICAL REMARKS ON AERIAL NAVIGATION.

BY SIR GEORGE CAYLEY, BART.

(Reprinted from the *Mechanics' Magazine*, No. 708, Saturday, March 4, 1837.)

Sir,—Permit me, through the pages of the *Mechanics' Magazine*, which widely circulates among the efficient mechanics of this engineering age, to call their attention to a subject of great national interest, and one that offers perhaps the most difficult triumph of mechanical skill\* over the elements man has to deal with—I mean the application of aerial navigation to the purpose of voluntary conveyance. There seems to be, if we may judge by the scattered notices in the public journals, a revived attention to this subject, not only in this country, but also in France and America: the experiments that have been made, and the investigation which it has undergone, lie almost unconnected in the periodical publications of the last thirty years; and hence every new speculator on the possibility of steering balloons, takes up

the subject merely on his own view; and as it requires much complicated calculation, as well as the utmost exertion of engineering skill, it is not surprising that we do not make much progress, especially when we consider the enormous expense of making experiments upon it on an *efficient scale of magnitude*.

Among others, five-and-twenty years ago, I paid considerable attention to the subject of aerial navigation, and collected or ascertained several of the leading points and laws of action that must be complied with to render any attempt respecting it successful. These were published in the *Philosophical Magazine* for 1816 and 1817, &c. I shall not, however, repeat much of what is there said, but proceed to state what I consider most conducive at present towards a final accomplishment of the ~~said~~ object in *noble* view.

In the first place, the enormous bulk of balloons, as compared with the weight they will sustain, causes the *difficulty* of impelling them, with sufficient speed to be of any utility, either by manual or engine power; and this *difficulty* is by many

\* This letter was commenced about four months ago; I am extremely glad to see how much this subject has grown upon public attention since that time, and how many excellent notices of it are contained in the last three monthly numbers of your Magazine up to September, which I have just received.



truly scientific persons considered as insurmountable, because they conceive that the bulk, which causes the resistance, must ever be commensurate with the weight of engine necessary to propel them by any species of waftage—and, consequently, as it will not do on a small scale, that it cannot on a large one. It is true, that it requires twice as much gas to sustain a 4-horse power engine as to sustain one of a 2-horse power (with their loads of fuel and water); but it is not true that the larger balloon, though perfectly similar in make to the smaller one, will, when driven through the air at the same velocity, meet with *double* the resistance—if it were so, the case of steering balloons would be hopeless, and on this mistaken ground many think it a vain attempt. This idea, resting at the very threshold of the invention, and which seems to present an insurmountable barrier, when probed and fully investigated proves to be false, and the investigation leads to an immutable law of proportion between the resistance and the capacity to carry weight or engine-power, which, on a very large scale, promises the most satisfactory result.

If balloons of the respective diameters of one and two, both being spherical, be driven through the air with equal speed, the resistance will be as the *surfaces* opposed to the air, and the surface of the largest will be four times greater than that of the smaller, and hence it will require *four* times the engine force to keep up the velocity; but the quantity of gas contained in the larger balloon is *eight* times greater than that in the smaller, hence it could sustain eight times as much engine-power; but four times that power would keep up the required velocity, and hence it could carry a cargo of the weight of its engine, and yet keep pace with the smaller balloon. The simple terms of the case are, that the surfaces (and hence the resistances) increase as the *squares* of the diameter of the balloon; whereas the capacity to contain gas (and hence the supporting power) increases as the *cubes* of the diameter.

From this *unquestionable* law it follows, that if similar shaped balloons vary in diameter as the numerals, 1, 2, 3, 4, 5, &c., the resistance they will meet with in the air, at the same velocity, when compared to the weight (or engine-power) they will sustain, will be as 1,  $\frac{1}{2}$ ,  $\frac{1}{3}$ ,  $\frac{1}{4}$ ,

$\frac{1}{5}$ , &c. This is a most important fact, and proves that as the law of relative diminution to resistance is *unlimited*, there must ever be, *theoretically*, some bulk in which any species of first mover, however sluggish in proportion to its weight, would find itself suspended, and its power adequate to propel that bulk with the velocity required. So far for the *principles* in action; let us now come to the real practical limits and bearing of the case.

The first thing that presents itself to our notice is the choice of a proper material of which to form a balloon for the required purpose; and the properties are those of being perfectly air-tight, light, and strong. Silk and Indian-rubber varnish are thus indicated, and have long been used; but in the larger constructions, that are suggested by the previous investigation, the expense of silk would almost prove a bar to real use. The double-cotton Indian-rubber cloth, used by Mr. Macintosh in his manufacture of air-tight seats and cushions of various kinds, weighs very nearly 1lb. per square yard, and will just sustain a tension of 2,500lbs. per lineal yard, that is, if the yard of cloth were rolled up and used like a rope, it would sustain any weight less than 2,500lbs. Of course, if used flat, as a portion of the surface of a balloon, it would sustain tension to the same amount. This cloth, when made to adhere to an adjoining breadth by an overlap of one inch with the Indian-rubber varnish, is air-tight at the seam; and is to the full as strong in resisting tension as at any other part, as I have found by experiments carefully made for the purpose.

As we now travel by railroad pretty constantly at the rate of 20 miles per hour, aerial navigation, though offering a direct navigable ocean to every point of our globe, would scarcely be worth cultivating, if not practicable ultimately at least up to that speed.

To be able to sustain the form of the balloon, when driven against the air with that velocity, implies that the condensation within must press rather more than the resistance of the external air; but at that velocity, by the well-known laws of resistance, every square yard near the centre, facing the line of flight, will meet a resistance of about 29lbs.; and hence the condensation over the whole interior of the balloon must give 29lbs. pressure



per square yard. More than this, balloons, to be really serviceable, must when at anchor, or by accident driven against obstacles, be able to resist the action of our most violent storms, which, according to Smeaton's table, go at the rate of 60 miles per hour, tearing up trees, and creating a pressure of 162lbs. per square yard.\*

This cloth can just sustain 2,500lbs. per lineal yard; and hence, by calculating the forces, it follows that the extreme limit of size to which a spherical balloon made of it could safely be carried when occasionally condensed to meet our storms, whilst at anchor, or when compressed against objects casually by them, would be 60 yards in diameter.†

Let us not be startled at this deduction, for in practice we may use as much less as we find convenient; and it is a feature of very great importance in favour of aerial navigation, that such a slight fabric is capable of becoming a safe vehicle of support to so vast an extent—and here it should be remarked, when balloons are made of forms differing from the sphere, that where for any considerable length they approach, as in elongated spheroids, to a cylindrical form, the cloth will only sustain near the minor axis half the pressure or condensation it will sustain as when in a sphere of the same

diameter; hence 30 yards would be the extreme limit of the shorter axis of an elongated spheroidal balloon made of this cloth.

As the netting, belting, or whatever means be adopted to enable the floating-power of balloons to sustain the burthens attached to them, must necessarily extend over more than half their surface, it would be best to complete the circuit, and thus add the strength of the netting to resist condensation, and fortify the cloth, especially near the shorter axis.

*Condensation* is a term that seems, and to a certain extent is, adverse to aerial navigation; but the whole condensation here required will only deduct 1lb. of buoyancy from every 120lbs. previously exerted by the gas, a sum too trifling to be of any consequence, and abundantly redeemed by the *firmness* it gives to whatever form it may be required to model balloons for obviating as much as possible the resistance of the air.\*

The next consideration is the proper form of the balloon for this purpose; and here it is obvious, that to extend their length horizontally, and thus to diminish their cross-section, is the leading point of the investigation. This will be limited by the practicable extent to which the structure can be carried without incurring weakness, in respect to the preservation of form, or inconvenience in the mode of suspending the car or body from the balloon. Ships and boats range between three and six times the measure of their greatest cross-section; birds between two and four. When convenience has pointed out the limits that must guide us in making use of *length* to obviate resistance, the *form* of the balloon, to meet the least resistance within these limits, is naturally the next inquiry. Unfortunately even the sagacity of Newton has not been able practically to grapple with this very interesting and intricate question; and his beautiful theorem on this subject will not apply to any of our gross fluids, which wedge themselves up by accumulation after they have struck upon the resisting body, and have no free egress to make room for others. The New-

\* These calculations are based upon the resistance being in the ratio of the squares of the velocities; and that a velocity of 21 feet per second gives a resistance in air of 1lb. to the square foot.

† The whole lineal measure of the circumference (being, in round numbers, 188 yards, capable of bearing 2,500lbs. each), can bear 470,000lbs.; whereas the whole area of the great circle on which the pressure takes place, being 2,840 square yards with a pressure of 162lbs. on each, only amounts to 460,000lbs.

In speaking of condensing the gas in balloons, which is a new feature in them, it will be necessary to provide a safety outlet by bringing a wide pipe from them, and placing the end of it a few inches under water; a column of  $3\frac{1}{2}$  inches of water would equal the condensation of 162lbs. per square yard. The escape of gas should be into a small empty balloon above the water, from which it can be pumped out at pleasure; the change of temperature in the climate also requires this structure. Eventually balloons will probably have a double casing, with common air, or, what would be safer, azote, pumped in between them. A small balloon to contain common air pumped into it, having a tube from it with its mouth a certain number of inches under water, and its bulk contained *within* the gas-balloon, would be the readiest way to meet all cases of condensation and expansion. With air-tight materials there would be no mixture of common air with the hydrogen, but this plan would require the materials to be perfectly so. To prevent danger from the fire of the engine, several wire-gauze divisions should be made in the chimney.

\* The expense of using pure hydrogen gas points out the necessity of balloons being perfectly air-tight, and when used as permanent vehicles, and on the true scale of magnitude, they will probably be made of thin metallic sheets kept firm by condensation, with separate light bags of gas within.



tonian solid of least resistance has a prow concave near the anterior axis; and as air is more elastic than water, the prow, if we may use the term, of birds, is also concave; whereas in fishes the prow, as in ships, is convex. In the absence of all good authority, I have proposed (at p. 400 of the *Philosophical Journal* for 1816) to copy the prow of the woodcock as there given by exact measurement. This bird was selected from its having frequently to pass 500 miles of sea at one flight; and because in its structure Nature seems to have united every contrivance to blend strength with lightness. The resistance of the air to its passage was the great obstacle to be overcome; and hence it is more than probable the best form (which, more than all the rest, would tend to the case of the performance) has been selected also. It is about  $3\frac{1}{2}$  times the length of its greatest cross-section.

The hinder portion of resisting solids is proved by experiment to be of as much importance as the prow; but as its office is to fill up the space, shielded from pressure for a time by the diverging momentum of the fluid driven off by the prow, any figure approaching to that of the cone answers the purpose tolerably well, if we may judge by the lengthened conical taper of the tails of fish; indeed it is a common expression among sailors, that a ship to sail well should have a "cod's head and a mackerel's tail."

We may rest contented to make our experimental balloon of an extended spheroidal form, and leave the rest to future improvement. The best form of ships remains in a great measure to be ascertained yet; although navigation has been bestowing wealth and comfort on mankind for so many ages under a rude approximation to it.

The next objects of inquiry are the power to be used in propelling the balloon, and the means of applying that power. Only two general modes have, I believe, ever been proposed by competent persons for this purpose. My friend Mr. Evans (see the *Philosophical Magazine*, for 1815, vol. xlv., p. 321,) tried with success to steer a small Montgolfier balloon by suspending a large oblique surface beneath it, which caused the ascent to be oblique in the direction towards which the upper edge of the plain was pointed; when the fuel failed, gravita-

tion made its return *obliquely* to the place from which it set out; had this plain been reversed when at the top of its rise, steerage towards the same point of the compass would have been effected in both cases by this sort of vertical tacking.

This movement implies the use of the fire-balloon; but it does not follow that the *whole* support must necessarily be given on that principle: suppose that two-thirds of the weight of the whole machine were suspended by a hydrogen-gas balloon, by any sufficient length of cordage (say it required from 50 to 100 yards), to ensure all danger from fire. Immediately above the car place a fire-balloon, likewise capable, when fully inflated, of supporting two-thirds the weight of the whole apparatus. When both balloons operated upon a large oblique inclined plain, with a power of ascension equal to one-third of the whole weight, it would render the oblique force very efficient in ascending; and when at the highest point of elevation the heated air is let off by the valve, and the plain reversed, one-third of the whole gravitation would give it an equally effective oblique descent. A machine on this construction would, on account of its progressive motion, obey a rudder, by which more exact steerage could be effected. It is certainly the most simple and least expensive way of primarily effecting the problem of steering balloons; but there is something unsatisfactory in being obliged thus to resort to such alternating heights and descents, implying such sudden changes of temperature, to say nothing of the devious and prolonged nature of the track, and the consequent waste of power. I send you a rough and hasty sketch of such a combination of balloons, having a large inclined plain suspended between them; capable of being pointed obliquely for either tack by cords from the car, as shown by the present position of the plain, and the dotted line A B, plate 1: The balloons are made in such proportion to each other as to be of equal power, their contents being as ten to four\* very nearly. Several strong ropes should pass from the collected cordage of the upper balloon through the interior of the lower one, as exhibited by the dotted lines, and be made fast to a large hoop forming the top

\* 27 ounces per square yard in hydrogen-gas; 11 ditto hot-air according to the French experiments on Montgolfier balloons.

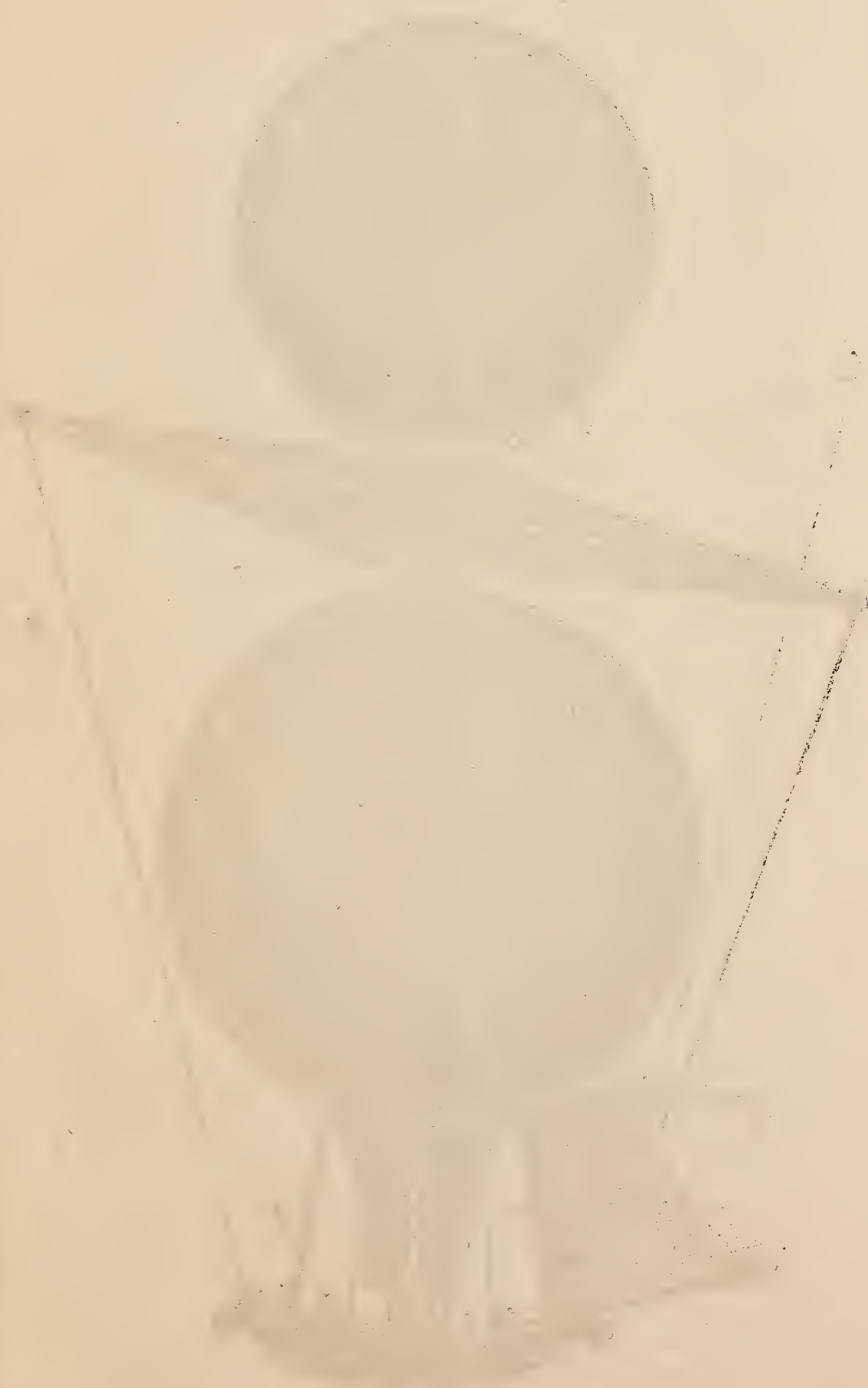




PLATE I.

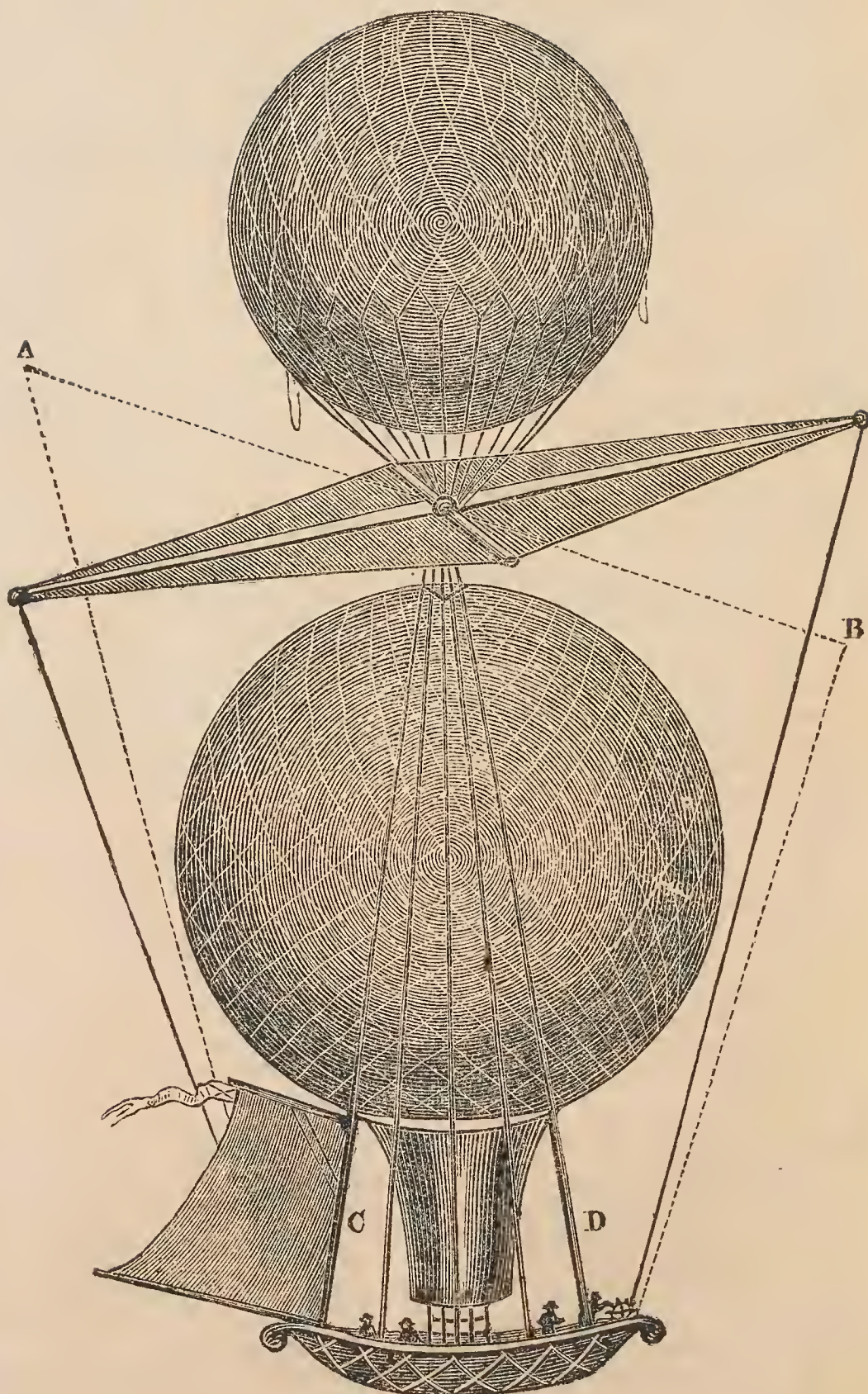






PLATE II.

Fig. 1.

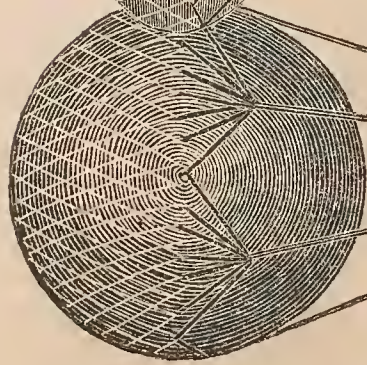


Fig. 2.

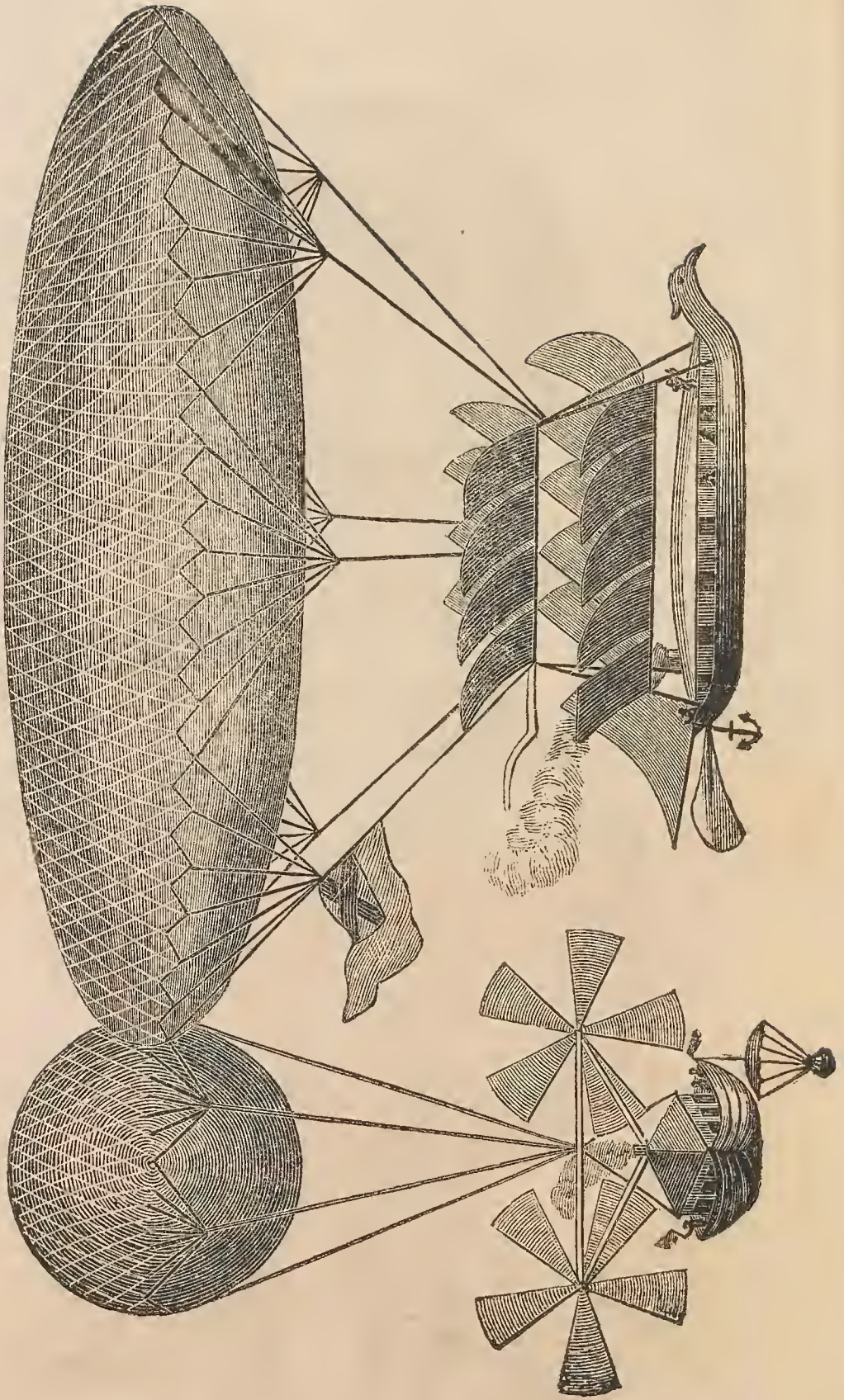
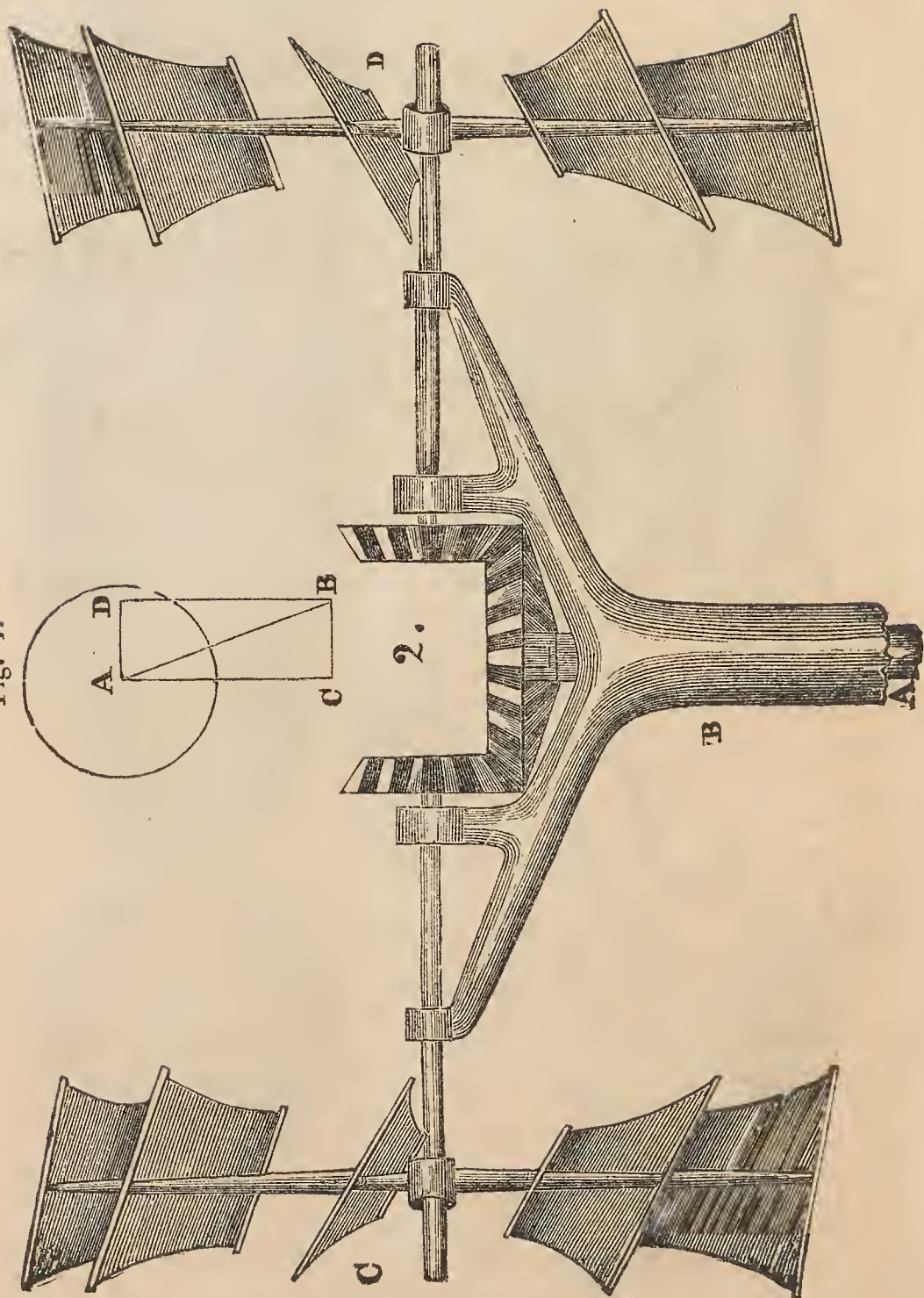






PLATE III.

Fig. 1.



of the chimney; this is partly held up by the two light masts C and D, and forms the means of suspending the car from both balloons, as the cordage from the netting of the lower balloon is also collected on this hoop. From the hinder mast C a sail may be conveniently braced to either side, so as to act as a rudder, and thus preserve a steady course. It is necessary to have a long chimney in Montgolfier balloons, when *speed* is required, to give sufficient pressure within to balance the external resistance, this must be 75 feet long to balance the resistance of a balloon at 20 miles per hour; and is, no doubt, a great inconvenience in this mode of action. The balloon sketched is supposed to be 30 feet in diameter, with 10 feet of chimney, thus giving 40 feet of columnar height at the top of the balloon, which would create a pressure equal to the external resistance, at a velocity of about 14 miles per hour. I do not offer this as a finished model, but merely sufficient to exhibit the principles in a visible form.

Steam, or any mixture of it with heated air, does not offer much prospect of advantage in filling Montgolfier balloons, and if it did, it could only be used when the balloons were of enormous magnitude, so that the proportional diminution of surface and increase of thickness in the materials, had greatly diminished the condensing power of the external air with Indian-rubber cloth of 1 lb. to the square yard, which would nearly absorb all the power of the 30 feet balloon I have specified, it would (according to some experiments I made, on cooling, with that cloth,) take about 100 lbs. of coke per hour to supply its condensation of steam at the ordinary temperature of our atmosphere.

Let us now consider the more direct plan of steerage by the wastage of surfaces to which engine power is applied. Some persons doubt whether if such power can be conveniently suspended to balloons, it would be efficient, because there are not *two* fluids to work upon, as the water and air in the case of ships; but this argument does not apply since the introduction of the steam-boat, where the wind has no concern in the movement; and, indeed we might as well doubt whether the muscular power in the bird's wing is that which propels it forward, as doubt that engine-power

if properly applied to balloons, will have a similar effect.

My friend Mr. Goldsworthy Gurney has just completed some steam-carriages, the boiler and engine parts of which weigh no more than 200 weight per horse-power;\* the supply of coke and water will be about (10 coke, 60 water) 70 lbs. per hour—say 30 lbs. more for the constant quantity left in the fire-place and boiler, and we have each steam horse, with its load for an hour in the weight of 300 lbs. If we take loads for several hours, and use no means of saving water by condensation, which might readily be done, the loads per horse-power will stand thus:—

	Lbs.
For one hour .....	300
— two .....	370
— three .....	440
— four .....	510

This is at present our best practical result. In theory, however, it seems possible that we may obtain a horse-power at very high temperatures, and working by expansion only, at  $15\frac{1}{2}$  lbs. of water and 10 lbs. of coke per hour. Lighter first movers than steam-engines may be discovered, and made applicable to propelling balloons; but let us take the case as our experience now places it.

Here, in fact, commence the real difficulties we have to contend with in rendering balloons serviceable to mankind; we have as yet only obtained the grounds of calculation, and these, when correctly followed up, place the result of the question not on any point of defective theory; but whether it is, or is not, practicable to construct them so as to be firm, air-tight, and manageable, when of dimensions far exceeding any experiments that have been hitherto tried, *we must be contented to give up balloons for purposes of locomotion altogether, or to attempt them on that scale of magnitude which a well-grounded calculation of their powers proves to be necessary.*

It cannot, however, be thought useless, boldly and unflinchingly to *investigate* the case, which, if practicable, offers us the floatage of an uninterrupted ocean from every man's door to any other point on the globe;—let not such a boon to our race be given up without a fair and vigorous effort to avail ourselves of it in our own age. To commence:—suppose a balloon be made of the Indian-rubber



cloth of Messrs. Macintosh and Co., in the form of an elongated spheroid thirty yards in diameter, and three and a half times that measure in length: although this would in bulk bear a strong resemblance to a hundred-gun ship, yet it would fold up into a cubical case 10 feet every way; and when inflated, is only a hollow bag received into a boundless ocean, where bulk ceases to be an inconvenience,—calculation proves that a condensation of one part in 120, will give it

firmness sufficient to resist storms without affecting its form; and the cloth is known to be air-tight under much more intense condensation: surely, then, we can scarcely doubt the possibility of making such a balloon, or of inflating it by pumping, with pure hydrogen-gas, setting aside at present all consideration of the *cost* of the experiment.

The weight of the materials may be estimated as follows:—

	Lbs.
Indian-rubber cloth at 1 lb. to the square yard .....	8540
Mr. Green's great balloon contains about 2000 cubic yards of gas; this balloon will contain 49,000; and if the weight of the other materials be taken in proportion to these numbers, we shall have for the netting .....	3360
The car .....	3000
The grapples and other matters .....	3425
	<hr/> 18325
Each cubic yard of hydrogen-gas gives 1·7 lb. of floatage; hence the whole power will be .....	85·255
From which deduct the 120th part for condensation.....	693
	<hr/> 84·562
And also the weight of the apparatus.....	18·325

There will remain as the free power of the balloon..... 66·237

Or about  $29\frac{1}{4}$  tons, which may be divided in any convenient proportions between the engine-power and its apparatus for waftage, the crew, and the cargo.

Before this can be done, it is necessary to have an estimate of the resistance of such a balloon when driven through the air at the velocity we propose to obtain. Extensive as this balloon seems to be, according to the best data, it could not be driven by the engines, &c. it could carry, at more than 17 miles per hour; and is better qualified to be driven at 14. It is extremely probable, however, that our data give the resistances of curved vessels considerably greater than is found to be the case in practice; but let us rigidly adhere to that which our present degree of information points out, and consider 14 miles per hour as the intended speed of our balloon. At this velocity there will be a resistance of 9 lbs. to the square yard when directly opposed to the current;—hence, as the greatest cross-section of this balloon contains 710 square yards, the direct resistance of such a surface would be 6390 lbs. Mr. Robins found that a sphere only meets with

about one-third of the resistance of its great circle, being as 1 to 2·7; others have found it still less, but experiments are scarce on this subject. With a view to the present inquiry, I made a light case of papers, glued together over a true spheroidal mould, 18 inches long by 6 in diameter, and loaded it so as to fall through the air in the line of its longer axis. A circle of 6 inches diameter was then loaded till it fell with equal velocity, keeping perpendicular, to the line of its fall, the weight required to drag the flat circle with equal speed, side by side, through a fall of 30 feet, was 4·8 greater than that of the spheroid (of course the *whole* weight of each apparatus was thus the measure of the resistance.) The additional weights used to bring the circle to an equal velocity with the spheroid, were so arranged within similar cases, as to give equal resistance. This spheroid was just three times the length of its minor diameter; whereas the proposed balloon is  $3\frac{1}{2}$  times longer than its breadth, which will materially diminish its resistance—and it may, therefore, be safely taken at not more than a sixth part of the resist-

\* Mr. Avery's American rotatory-engine will probably be still lighter if the loss of power do not balance its simplicity of structure.



ance of its great circle,\* and in this case the resistance of the balloon at the proposed velocity will be  $\left(\frac{6390}{6}\right)$  or 1065lbs.

—and as the speed at which this force must be supplied is 14 miles per hour, or 21 feet per second, it is equal to  $1065 \times 21$ , or 22365lbs. raised one foot high per second, which divided by 550, the number of pounds raised one foot high by a steam-horse, quotes the power required as that of rather less than 41 steam-horses, call it in round numbers a 40-horse power, provided it could be applied from a solid fulcrum on the earth; but whatever kind of waftage may be employed, there will be a loss of power by its acting upon a rare and also a receding medium.

For the sake of perspicuity, suppose that the surface employed to propel the balloon be equal to that of its great circle, then it will receive as much resistance (following the law of the squares of the velocity, and the resistance of the spheroid being one-sixth of that of the great circle) at about  $8\frac{1}{2}$  feet velocity, as the balloon does at 21 feet; but before the wafting surface can give this resistance, it must go back with  $8\frac{1}{2}$  feet more speed than the balloon goes forward, so that the engine-power is working at a velocity of  $(21 + 8\frac{1}{2})$   $29\frac{1}{2}$  feet per second, and this requires the power to be increased as 21, the former velocity, is to  $29\frac{1}{2}$ , or from a 40 to a 57 horse-power. Let us, then, consider our balloon as requiring, in round numbers, a 60-horse power.

The weight of the engine at 510lbs. per horse-power, with a load of fuel and water for four hours, will be 30,600lbs., which deducted from the 66,237, leaves 35,637lbs. of free floatage. Suppose the machinery for waftage to weigh as much as 13,000lbs., then there would still remain 22,637lbs. to convey passengers or cargo, say 100 men and their ordinary goods, or 10 men and a cargo of 21,000lbs. —about 9 tons.

This estimate was made on the plan of

\* Mr. Tredgold, at p. 330 of his excellent work on the steam-engine, gives us all the particulars of the *James Watt* steam-boat, the length of which is to its greatest cross-section under water, as 5.7 to 1; and when the power which its engines can supply at the velocity, the paddles move with in still water is taken as a criterion of its only opposing force, the resistance, it does not appear to be more than one-sixteenth part of what the cross-section would receive. Hence we are probably allowing a much greater resistance to our balloon than on a large scale it will receive.

the direct waft backwards, merely for the sake of being more readily followed in its various steps; and to avoid rendering the case intricate by adverting to that resolution of forces which takes place in oblique waftage, as in the wings of birds, the fins and tails of fishes, and in that which I am about to notice as applicable to our purpose.

It appears from the experiments of the French Academy, on the resistance of water at acute angles, corroborated by the effect of the wings of birds in air, which give support to their weight when skimming at a very acute angle, that by oblique vanes, reversing, as it were, the action of the sails of a wind-mill, the proper fulcrum or resistance for the engine-power to work upon can be had at a velocity of 25 feet per second, in lieu of  $29\frac{1}{2}$ ; and hence a 47-horse power will be sufficient for our purpose—in round numbers, say a 50-horse power in lieu of the 60-horse power on the former plan. This cannot be proved without a complicate diagram, and an explanation that would obtrude too much upon your pages, and most probably on the patience of your readers on the present occasion.

This will enable us either to add 5,000 more to the cargo, or, by using a 60-horse engine, to go with more speed.

Many persons erroneously suppose that any propelling force of waftage, when acting in the direction of the *car*, will not tend to propel the *balloon* above it. Let A, fig. 1, plate 3, be a balloon; let B be the position of its car, propelled beyond its centre of suspension, A, by any given power of waftage. Draw AC perpendicular, and CB parallel to the horizon; and let these lines be made in the same ratio to each other as the weight of the car is to the propelling power; then the line AB will represent the whole action of the car upon the balloon. Draw AD and BD respectively parallel to the two former lines; and as the floatage of the balloon is equal to the weight of the car, BD will as truly represent the floatage as AC does the weight; and, as the propelling power is, as soon as the speed becomes uniform, equal to the resistance, being the cause and measure of it, AD must as truly represent the resistance as its equal CB does that of the propelling power. In this position, then, all the powers are balanced in equilibrio; but there will be no resistance till the



balloon has the velocity necessary to generate it, and this it finds at the same speed in the line AD, as if it were moving along its equal CB.

I will here take advantage of the same diagram to observe, that if a balloon be supposed to be at anchor in a gale of wind, by the car being secured to the ground, and the line AD be taken to represent the force of the wind, and BD the power of floatage, then AB will be the position the cordage will fall back to. The resistance to the prow of the balloon in question, at a hurricane of 60 miles per hour, would be about 20,000lbs.—deducting the car then on the ground, its floatage would be about 63,000—so that it would fall back about one part in three, which are the proportions purposely taken in the diagram, in order to prove that permanently-filled balloons would ride out storms when properly secured, without the danger of being driven to the earth and damaged.

Some persons are, however, disposed to strike at the root of all discussion as to steering balloons, by affirming that no waftage can propel bodies suspended in one and the same element in which the waftage takes place. These persons I will refer to p. 172 of *Nicholson's Chemical Journal* for 1809, where they will find a description of a small machine, which they can make for themselves in a few minutes, that will elevate its own weight from the table to the ceiling, *merely by the waftage it creates*. The machine I have there described is a mere toy, but the *principle* on which it acts is capable of the most powerful and extensive application. I send you a view of its application to driving balloons, copied from a paper of mine at p. 81 of the *Philosophical Magazine* for 1817 (see plate 2, fig. 1), where there is likewise given a side elevation of a balloon with oblique wing waftage (fig. 2). The former by vanes revolving on an axis, the other by the heeling up and down of the surfaces in a reciprocating action, as in the bird's wing.

There is in one of the early volumes of the *Philosophical Transactions*, an account of propelling a boat with considerable velocity by men working this sort of waftage against the air; but I should prefer trying the more uniform action of the oblique vanes. More than one may be

used on the same axis; and they may be so constructed as readily to apply their power, either to propel or retard, elevate or depress, as occasion may momentarily require. This will be obvious on inspecting fig. 2, plate 3.

Let the power of the engine communicate opposite movements to the reversed sets of fliers, C and D, through the cylindrical shaft A, and the wheels connecting them; the whole free power of the waftage will act in the line of their axis of motion. Conceive this axis to be moved into any position with respect to the horizon, by turning the hollow mast B (by which, through a suitable collar or socket the apparatus is supported from the car), and the balloon will be propelled accordingly. In the balloon we have been estimating, the four sets of such fliers would have to be 10 yards in mast or radius; and each sail would contain 30 square yards of surface. The figure given is intended merely to explain the principle of this action in the most distinct manner. In practice, this fabric, to unite strength with lightness, would be braced like the masts and sails of a boat; and its main strength derived from the ropes or metallic rods forming three braces.

Communicating centrifugal force to air by means of a hollow drum and fans worked by the steam-engine, is another means of getting a propelling power conveniently applicable in every direction that may be required; for by having a moveable mouth-piece, from which the air escapes, the re-action will always be in the opposite direction. Though convenient in this respect, it is too wasteful of power to be used for balloons, unless for small experimental purposes. Many other considerations remain untouched, upon; but I have already obtruded too much upon your pages with these dry details. The *subject*, however, is one of great interest, not merely in a mechanical point of view, but as to its stupendous effects on mankind at large; civilisation and, I trust, *perpetual peace* are in its train of consequences.

To such as have honoured me by wading through the train of this investigation, I will beg to remark, that they must not blame me for *wilfully* introducing such acres of cloth to their notice. Calculation from well-known data proves that balloons can only be driven with



sufficient speed to be useful on the scale of magnitude I have pointed out. Let the question be put where it truly rests, whether such fabrics *can* or *cannot* be made and managed. The case is one evidently too great for individuals to make efficient experiments upon; and I am glad to see that some of your correspondents have recommended a subscription purse, and I hope that plan may be followed up. I proposed this in the year 1817, in the following terms (page 28, vol. 1., *Philosophical Magazine*):—

“We, the undersigned parties, enter into the following subscription for the purpose of ascertaining how far the principle of balloons supporting heavy burthens in the air may be made useful as a means of conveyance.

“No person to be called upon for his subscription money till at least 1000*l.* be subscribed for.

“When the subscription has reached this amount, an annual Committee of seven of the subscribers to be elected. Every subscriber of 1*l.* and of less than 5*l.*, to have one vote. Subscribers of 5*l.* to have two votes; and subscribers of larger sums to have one additional vote for every additional 5*l.* they subscribe.

“No experiments to be undertaken but by order of the Committee, who may call in the advice of such civil engineers as they chose to consult.

“An annual report of the application of the funds, and the result of the experiments made, to be printed for the use of the subscribers.

“These regulations being the basis on which the subscription is made, cannot be altered; but subsequent rules not militating against these, may be entered into at a general meeting of the subscribers expressly convened for the purpose.”

The late Mr. Lovel Edgeworth immediately before his death became a subscriber of 50*l.* towards this fund, which his deservedly celebrated daughter subsequently offered to make good. Mr. Evans also became a subscriber; but the age was not then ripe for the subject—steam-boats were in their infancy, and railroad velocity unknown; twenty miles an hour then seemed monstrous and chimerical; now our only fear is that balloons will not have speed enough to satisfy our locomotive mania. I must not mention the respected name of Edgeworth without stating that he puts in a previous claim to that of Mr. Evans (see *Philosophical Magazine*, for 1816, p. 185,) to the principle of steer-

ing balloons on the tacking plan by the use of the inclined plain. He appears to have communicated the plan to Monsieur Montgolfier in the year 1782. Mr. Evans is, however, the first person that has proved the invention experimentally.

Balloons, as has been long ago observed, ought not to be made all in one, but have several departments for the gas, like “the stomach of a leech,”—and should the promoters of aerial navigation get up a purse and combine their efforts during the present season, I should strongly recommend that Mr. Green’s large balloon, and that gentleman’s great experience and skill, be put in requisition; that two other of the largest balloons that are in town be packed at opposite sides of this large one, under one netting made in compartments for the purpose; the whole free floatage may then be expected to be equal at least to 23 men; let the crew be Mr. Green and his assistant, and let the weight of twenty-three men, say 3400 lbs., be occupied by the lightest possible tubular boiler and high-pressure steam-engine of 5-horse power, which, no doubt, would be got up with a 4 hours’ load, at 2500 lbs., leaving 1100 lbs. as the weight of the fliers for waftage. This might be expected to drive the balloons at from seven to eight miles per hour, which would be quite sufficient as a *first* experiment.

As men have the choice of time, in a great degree, those winds that are tolerably favourable to any intended voyage, can often be selected; different current in the air can also be occasionally met with, so that balloons offer more advantages from the wind, than inconvenience from its occasionally being too strongly against their line of sailing.

I have been applied to by an ingenious foreign mechanic, now in Rome, who affirms, that by a particular apparatus of his own, he has guided small balloons with considerable velocity; that he is in possession of an engine four-times more energetic, weight for weight, than the lightest of our steam-engines (the powers of which I gave him, as stated in this letter), and that he wishes much to exhibit the proof of what he says, in London, should he meet with any persons who would pay the expenses of his journey; previous to which, he offers to satisfy any of the British residents in Rome that he can perform what he asserts.

Should a good subscription-purse be obtained for general ballooning purposes, it may be just and desirable to give this humble workman an opportunity of substantiating his claims, by thus previously exhibiting his machine to the celebrated artists, Mr. Gibson and Mr. Macdonald, or other well-known British residents in Rome. For my own part, I shall be ready to become a subscriber to any rational plan for trying experiments upon balloons on truly scientific principles, and free from any *jobbing* or *exhibition-making* speculations.

Let the friends of aerial navigation be

called together by advertisement in your pages, at the instigation of a few names favourable to the project; let a place—say the Adelaide Gallery, if the proprietors permit it—and some convenient day in next month, be named and from this meeting let such resolutions emanate, as may best ensure the progress of *The Society for Promoting Aerial Navigation*.

I am, Sir,

Your obliged and obedient servant,

GEORGE CAYLEY.

Forwarded Jan. 23, 1837.



## NOTICE.

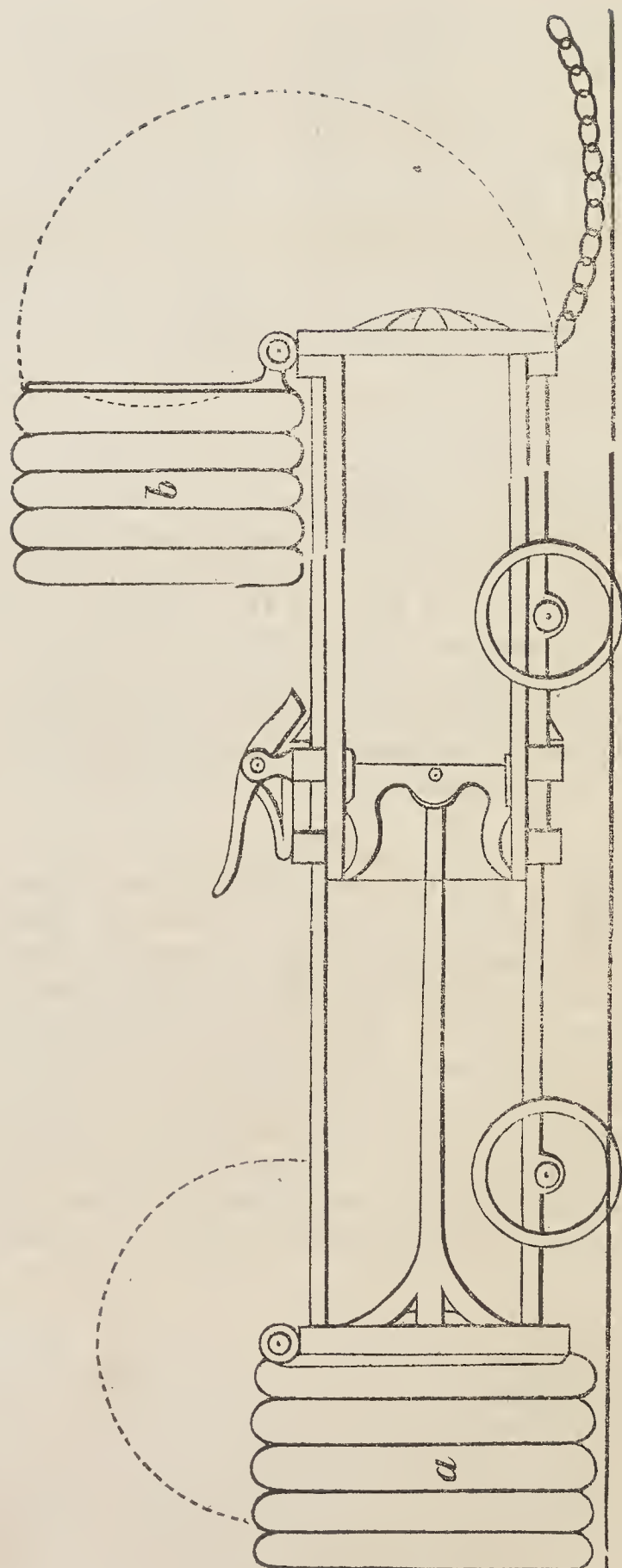
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In reprinting this Essay from the "Mechanics' Magazine" I am glad to have the opportunity of stating that I was mistaken in thinking that Mr. Curtis had not contemplated applying his tension rope to mechanical signals, at the time I first saw his invention, as noticed very lately in the "Railway Times." He informs me that the plates pointing out this part of his invention were mislaid, and consequently could not be printed with the other, or voluntary part of his plan, and this led to my mistake ; although he says, some verbal allusion was made to the mechanical principle also, which had escaped my notice.

My object in writing this Essay was, to collect from others, or point out, as well as I was able, all the various mechanical arrangements for ensuring safety in Railway travelling ; and if I have unfortunately, in the rapid progress of railroad inventions of late stumbled upon the matured plans of any others beside those alluded to, I must beg them to consider that, in any of the suggestions I have proposed, they were not given as finished models, or as best fitted for actual service, but to point public attention to their *practicability* by exhibiting *one* means of effecting each purpose. Nothing can more completely fall in with my views than to be enabled to shew where, and ~~by~~ <sup>from</sup> whom, the improvement contemplated, can best be obtained.

Hertford Street, May Fair,  
25th February, 1841.

Fig. 1.



# ESSAY

ON THE MEANS OF PROMOTING

## SAFETY IN RAILWAY CARRIAGES.

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BY SIR GEORGE CAYLEY, BART.

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The enormous advantage of railway communication is now fully appreciated by all classes of society; and even the chariot and four is laid aside, or, disengaged from its proud steeds, hoisted on the sturdy back of its rival, to grace the more plebeian vehicle by the fascinating halo of its coronet. But our delight in railway speed is unfortunately chilled by the accompanying drawback of its danger. Within the last three months many serious accidents destructive of life, under very awful circumstances have occurred; and though on comparing the millions of persons who have availed themselves of the benefit of railroad travelling without injury, with the few that have suffered, there is reason to believe, that a greater per centage of fatal accidents prevails, mile for mile, in carriages drawn by horses; yet as it is now evident that the former will eventually extinguish the use of horses except for local purposes, it becomes the duty of the legislature to apply the best means in its power to insure safety of life and limb to her Majesty's liege subjects of all ranks; and not to leave them exposed merely to such measures of care, as the directors or agents of railroads may choose, when enjoying, danger or no, a complete monopoly of the public means of conveyance. No doubt, were railroads to be constructed now, with all the knowledge gained from the experience of the past, much additional safety might be attained. Supposing, for instance, that instead of making the wheels, as at present, sink about an inch and a half by the side of the rails on which they run, they had three inches of hold before they could be lifted out, many small substances that would now throw them off would not have that power; and probably the cases of accident from that source would be diminished one-half. Many other similar improvements experience must have pointed out; and it would be very useful to draw all this experience to a focus by a parliamentary committee of enquiry, not only as respects the construction of the machinery of railroads, but as to the best code of precautionary measures of management;—the sufficiency as to the numbers and quality of officers—the arrangement of signals—and all the various manipulations required to give the greatest possible safety in combination with



the required velocity of the trains. Such a committee might go still further, and by calling upon our first-rate engineers, and other scientific persons, to suggest such improvements as they think attainable, much expedite the ordinary progress of this new art to maturity.\* With a view to stimulate the legislature to go into this enquiry, it may be well to consider some of the leading points of danger, and to suggest such means of counteraction as may be most obviously applicable to each case;—more in the expectation that these or similar means may be matured by the proper authorities in mechanical science, than as worthy of application in the crude state in which they are thus pointed out.

It is obvious that the danger of being conveyed with great velocity, arises from the possibility of that velocity being too suddenly stopped; and before we can judge of the efficacy of a remedy for this evil, it is necessary to have a knowledge of the degree in which it prevails.

Twenty miles per hour, including stops—say twenty-one actual velocity—is about an average speed on most railroads. Were this suddenly stopped, as against the abutment of a bridge, &c., the blow would be equivalent (without buffers and cushions) to falling from a height of sixteen feet upon deal boards,—if happily they escape a more severe contusion from some protruding point, as the elbow of the opposite seat, or the scull of their vis-a-vis. This danger has a tolerable parallel in what might be expected, should the drawing-room floor give way, and precipitate its inmates on to that of the dining-room beneath. It is not necessary to add to our dislike of such a catastrophe, but yet it is useful to have a true measure of the degree of danger from this source; and it is sufficient to state the fact, that double the speed named, or forty-two miles per hour is frequently attained in descending inclined portions of the way. In this case the blow would be equal to that received in falling from a height of about sixty-four feet. This is falling from the chimney top to the cellar—an experiment not to be tried twice in one man's life time.

To meet this danger, every railroad carriage is provided with two buffers at each end of its frame; these are formed of leather caps well stuffed, and fixed on an iron shank, which presses on strong springs placed under the frame for that purpose. These springs can, when great force is applied, recede about a foot before the buffer can be pressed home to the frame. This is a very admirable contrivance, and perhaps the best that can be applied in each carriage separately. Suppose it may require a force of four tons to press home the two buffers, and that each loaded carriage be two tons weight, the power of resistance in the two buffers will be equal to what they can restore in their recoil, which will be equivalent to raising four tons half the length of the action of the spring, or six inches, and equal

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\* This Essay was originally printed before Sir Frederic Smith, and Messrs. G. R. Porter and S. Laing, had issued their very temperate and valuable Report to the Right Honorable the President of the Board of Trade, under Lord Seymour's Act. That Report, however, does not touch upon the mechanical part of the subject.

to two tons raised one foot. But the velocity of twenty-one miles per hour in the carriage is sufficient, if so applied, to raise its weight of two tons, sixteen feet; hence the buffers would only absorb an eighth part of the shock in the first carriage. This is, of course, but a rude approximation to the truth, through the means of an hypothetical case; but it may aid our ideas in seeking a remedy, and it points out that although the buffer cannot be dispensed with, yet that it does not carry out the principle of an elastic retarder to a sufficient extent.

It is obvious that to take full advantage of this principle, there should be in advance of the engine, and in the rear of the last carriage in every train, a separate vehicle devoted to carrying a buffer of sufficient power to save the whole train and its engine.

The first idea that naturally presents itself, and has probably done so to many, is that of making a series of mattresses, of some elastic matter, to be so packed on the frame of a carriage (say for twenty feet in length) as to be greatly compressed on meeting with any resistance; and I am by no means certain that any other contrivance will do much better; but in these engineering days we shall never be contented without some more precise and workman-like method; and luckily the elasticity of air when compressed by a piston offers a ready means for effecting this purpose with such precision as to be subject to exact calculation, and of course capable of being adapted to the power required. The piston in this case possesses the advantage not only of receiving the accumulating resistance of the compressed air in front of it, but also the retardation, if worked through a stuffing box, occasioned by forming a vacuum behind it, which greatly increases its power.

An idea of such a general buffer is given in the accompanying sketch fig. 1. The condensation only of the atmospheric air at its usual density is provided for in this construction, for the purpose of making the sketch less complicated; but if the now open top of the cylinder be supposed to have a cover, with a stuffing box in it for the piston rod (when properly adapted to that purpose) to pass through it, both these powers of retardation might be used. When sufficient power for the trains, can be obtained by condensation only, it will be well to make use of the instrument in that way, because it is then more secure in cases of extreme violence from being so injured as not to be able to perform its functions.

Suppose the air cylinder to be six feet in diameter, and the piston to be able to condense the whole charge of air into one-twelfth part of its original bulk, when it has been pushed in ten feet; the power of retardation commencing at zero, and being at the termination about 165 lbs. per square inch, may, including friction, be taken at about 35 lbs. per square inch on the average for the ten feet of stroke; which, on this area of 4071 square inches, amounts to about 63 tons. Hence the whole power of the retardation may be taken as equal to 63 tons raised ten feet.

The velocity of the ordinary trains, as has before been shown, is equal to lifting their weight to the height of 16 feet, and hence it



requires about one ton and six-tenths of retardation for ten feet, to balance one ton of the train for 16 feet; consequently this general buffer will be equivalent to about 39 tons of the train. This, however, will be sufficient; take the buffer itself at 8 tons, the engine at 12, and the first 9 carriages at 18, making 38 tons in all.

If placing the stuffing box on a sliding plate in the cover be sufficient to obviate the danger of the piston rod not working freely, if slightly deranged by violence, the buffer may be made of considerably smaller size, and of course more light and convenient. By leaving in this case any required portion of air behind the piston, the power of retardation from the vacuum would not commence abruptly, and may thus be regulated also in its intensity. The cylinder must be furnished with a valve or stop-cock under command, at the end, to permit the escape of air whenever it is required to run the wheels nearer together, so as to place them on the turning platforms; and the frame connected with the piston, and which runs freely in a sheath external to the cylinder, both above and below it, is held by a spring catch in its place till some object requiring the action of the buffer be struck.

The buffer is also furnished with stuffed pads at each end, *a* *b*, to take off the first shock of the *vis inertiae* of the piston, its frame and wheels, which are necessarily ponderous to be of sufficient strength. These pads turn upon hinges, so as to shorten the length of the carriage when required, as may be seen in the sketch, where the hind one *b* is turned up.

It may be thought superfluous to place a general buffer behind the trains; and if *every* train be provided with one in front it would be unnecessary; but engines unattached to anything are frequently moving about, may escape, and with unrestrained velocity run in upon a train at rest. If this be too remote a contingency to deserve notice, the hind buffer may be dispensed with—however agreeable it may be to have two buffers between us and danger in most cases, and certainly one in all. It may be thought, in lieu of the air buffer, which is necessarily of considerable weight, that a series of mattresses being lighter, and of course not absorbing so much engine power to propel them, would be preferable; but it ought also to be considered, that the leading vehicle in a train, in proportion to its lightness is more readily thrown off the rail and thus gives a wider range to accident, which it is our great object to avoid. The pads of the air buffer, as before described, show a flat face, which, upon the whole, I think likely to prove the best form; but they might in front have the form given them of a gothic arch, for the double purpose of obviating the resistance of the air, one of the great impediments to velocity, and the better to cast light objects, or human beings, off the line of the rail with an oblique and less forcible blow: but here again the same objection arises—we are increasing the risk by a side force of driving the buffer carriage off the rail. These are matters deserving of serious inquiry; and which scarcely any thing but practice can finally determine.

When we meet a train coming at full speed on another set of rails,

the rush past is really terrific; and conveys an idea that were they to meet on the same rails nothing could save either from destruction. There is quite terror enough in the public mind on the subject of railways; and it is therefore well to make calm estimates of the degree of danger attending even such cases of possible occurrence as this. Paradoxical as at first it may appear, the shock to each train in this case, if of equal weights and velocities, would not be greater than if it had gone against any solid object; for if the elasticity of the buffers be supposed perfect, each train would rebound with the same velocity it advanced; and the retardation at the moment, of each from the other, is just sufficient to furnish the resistance necessary to produce the equivalent rebound.

If equal trains meet, having unequal velocities, say one at ten miles per hour, and the other twenty, they will average the shock between them, the slow train getting more shock than it would against a solid object and the other less.

Heavier trains meeting light ones with the same velocity will communicate the greater share of the shock to the lighter ones—for the momentum of each after the shock will be equal; and of course the velocity of the rebound, which is the cause of danger to passengers, will be greatest in the lighter train.

There is one case truly terrific in the meeting of trains, and that is, if, when on different rails, any very strong portion of one carriage firmly chained to the rest, should, from getting displaced, catch some weaker portion of the other train, the latter would successively give way, and the whole force of both trains be expended in the work of devastation. Fortunately this is a most remote contingency, and may be rendered, by precautions that will be pointed out, almost impossible.

Having taken a cursory view of general train buffers, there is something yet to be considered in a minor way respecting the application of elastic matters to secure safety to passengers.

The padded cushions on all sides of the first class carriages should, in a coarser, but not less efficient way, be extended to all carriages for passengers, for each man's life is equally valuable to himself, and should be equally protected.

It was very properly suggested lately in some of the public papers, that railway carriages ought to be fitted up for only single rows of passengers, so that no one ought to sit opposite to another. I have always held this opinion, and feel more confirmed in it than ever, by finding that others agree in it. As the feet of one set might pass under the seats of those in front of them, little space would be lost by this arrangement when new carriages have to be built. In the mean time, some one has suggested a broad padded belt to be placed in front of each passenger, to retain him in his place in case of accident, and to prevent a collision with each other. How John Bull may relish this sort of straight waistcoat, I do not know; but perhaps some modification of it for his own safety may be tolerated.

If single rows of passengers be adopted, a few carriages might also be fitted up on the same principle for night trains, with horizontal



berths one above the other, to sleep in, as in packet boats. These would at all times be of important use to invalids and elderly persons, and if well padded on all sides, would be as secure as the nature of the case permits.

There is one point that seems unaccountably to have escaped the notice of railroad engineers—and that is, placing the engines under regulation as to velocity, by the usual mechanical means. The common expanding centrifugal force regulator, for cutting off the steam when the engine is going too quick, is as applicable to railroad purposes as to engines in any other situation. The Directors may agree that no trains shall on any pretence be permitted to go at more than a given number of miles per hour; let them set the regulator accordingly, and let it be locked up in a case of which they have the keys; the result would be certain. But where the declivity is such as to cause a greater velocity without engine power, the regulator might be so connected with a lever that when the steam was cut off, it should, if the speed continue, liberate the catch of a forcible spring break upon the wheels of the engine; a matter which any of our common engineers could contrive if required.

The next subject of serious importance to the safety of railway travelling is to have such a mechanical arrangement as will cut off the free action of the wheels from the moment of receiving any shock; and also to have the power of so doing at any time according to the will of the conductor when he perceives danger at hand. This may be done in several ways, and some drawings for this purpose were prepared by Mr. Worsley and myself last year. I understand the subject is now taken up by Mr. Stephenson, under whose auspices it can scarcely fail to be ripened into practice.

To elucidate the subject, rather than to submit a perfectly matured plan for the purpose:

Let fig. 2 represent the front wheel and end of a railway carriage-frame. On the axle of the wheel let an arm A, terminating in a concentric shoe B, turn freely. Connect this arm by the rod or link C, with the shank of the buffer D, which is held in its place by the buffer spring E. It will be evident from this arrangement that when the buffer is pressed back, the point of the shoe B, will approach the rail, and if further pressed, the wheel will get upon it and the carriage instantly be on the drag; and this can be made to take place at any required degree of force applied to the buffer.

To get off the drag the carriage must be slightly backed, to which there will be opposed no resistance. The perforation in the arm of this drag to receive the axle must be a little elongated in the direction of its length, so that the wheel, which must not touch the drag when not in action, may by its own weight rest firmly upon it when brought under it. A spring may perhaps be found requisite to regulate this simple process. If the two front wheels be thus converted into sledges whenever any serious resistance occurs to the train, perhaps it may be sufficient; but if required, the hind wheels may undergo the same change, by connecting similar drags applied to them with the front movement. As the front wheels, however, are so

readily made available as drags by the involuntary action of the buffers, in times of accident, it will probably be best, to furnish the hind wheels with a similar apparatus to be put into action at the will of the conductor of the train. A little difficulty arises in conveying the pull of a

Fig. 2.

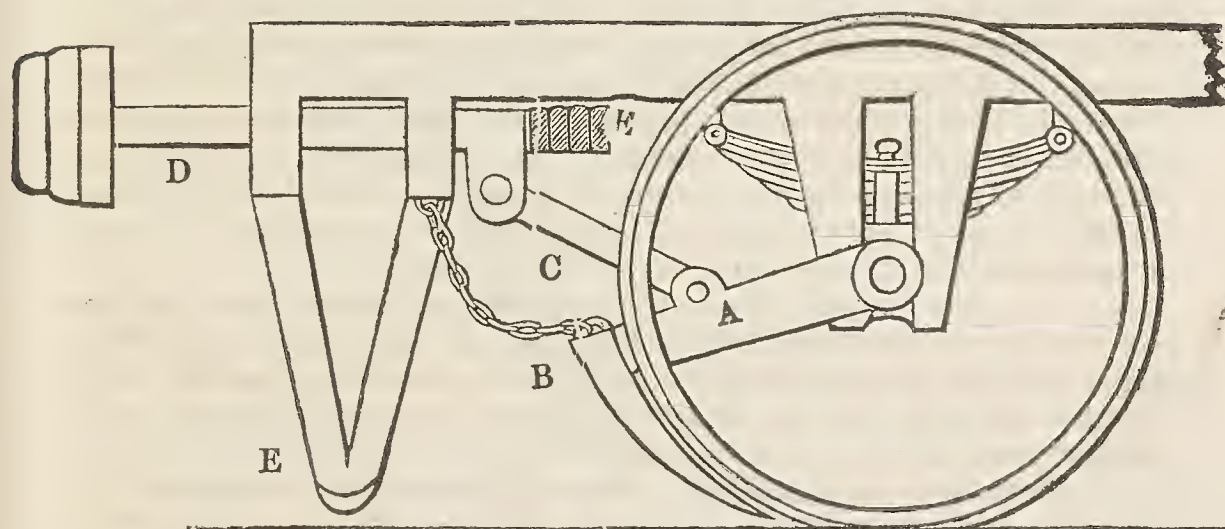
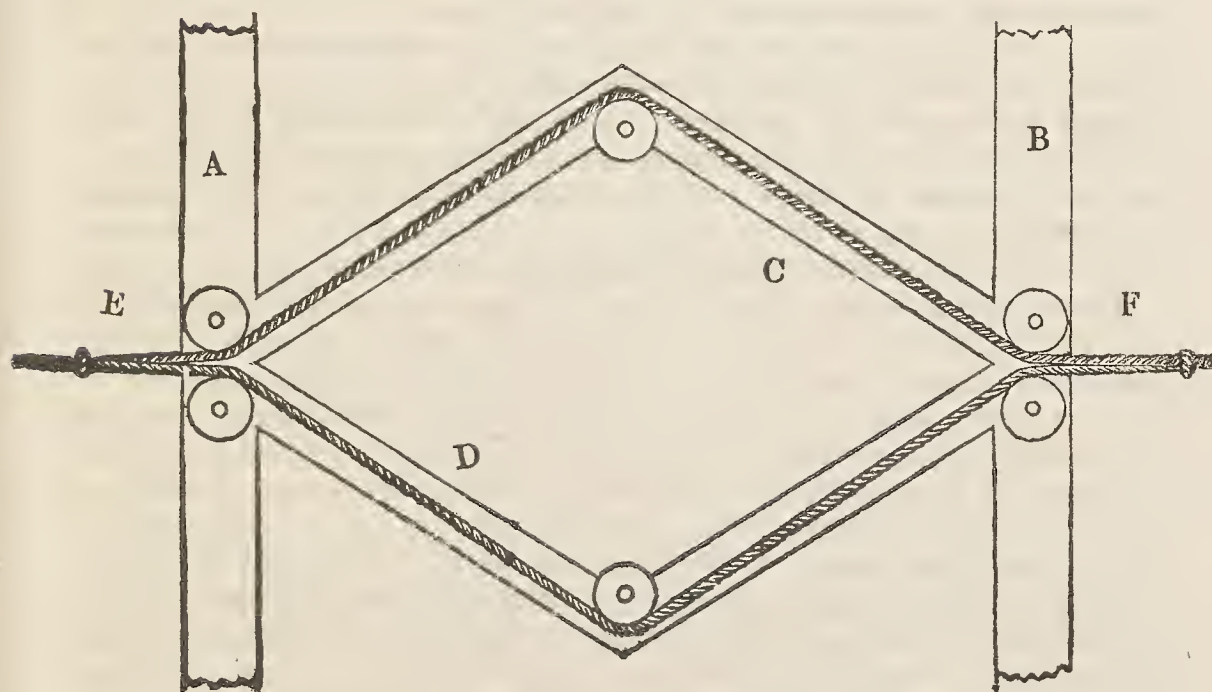


Fig. 3.



chain or cord from the place where the conductor stands to the carriages at a distance from him, because the play of the buffers keeps continually altering the distance of the carriages from each other. To obviate this difficulty, let A and B, fig 3, be the hind part of the frame of one carriage and the front frame of another, where the buffers keep them asunder. Suppose C D to be a free jointed parallelogram framework, so made as to be put on at pleasure by a couple of



bolts, and carrying guide pulleys for the rope or chain E F, which is divided into two portions to follow the form of the frame, and unites again on the other side. By this arrangement, it is plain, that although the jointed parallelogram frame can accommodate its diagonal length to every play of the buffers still each of its sides continues to be of the same length, and hence the chains that correspond with them will neither shorten or elongate as respects the distance of its two extremes E, and F, from the frames A, and B, so that a steady tension can be transferred from the conductor throughout all the train, if furnished with these parallelogram frames properly fitted up for retaining the chain or rope in the pulleys; consequently the drags on the hind wheels can by this means be brought to act, at the will of the conductor, in every variety of distance each carriage may chance to be from another, at the time the drags are wanted.

Another great branch of inquiry respecting railroad carriages is, how best to secure them from getting off the rails, and many things might perhaps be suggested for an entirely new work, but the main question is, what can be done as things are now arranged? and without some additional means nothing can be done but by precautionary measures on this head. Should the railroad companies by their own power, or by the assistance of Government, not weighing money against life, choose to fill up the interval between the rails, excepting near stations, with masonry well clamped together (or even strong oak sleepers near each wheel, if nothing more can be afforded), great additional security would be gained; and such a wall would be the means of keeping men and cattle out of the path of the carriages. Should a wheel break down or come off, much additional security would also be derived by having four feet to each carriage, one of which is represented at F, fig. 2, which would sustain the carriage like a sledge as soon as the wheel in its vicinity failed, and not cause any friction by touching the rail before its services are required.

The French in their imitation of the ice mounds, which form so striking a portion of the amusements of winter in Russia, were the first to use the railroad with great speed. The average velocity of the carriages on their Montagne Russe, I ascertained, in the year 1818, to be 17 miles per hour; but a part of the course was purposely retarded by remounting to a slight elevation, so that the speed was full 30 miles per hour in some part of the way.

To render these carriages secure on the rails, four small wheels were placed under a projecting part, immediately beneath those which supported the carriage; the lower wheels did not touch the under part of the rail, unless the velocity caused the upper ones to jump half an inch, or perhaps an inch, when they effectually prevented the carriage being thrown off.

In the construction of new railways, some modification of this principle might be adopted, and a middle rail, as was lately well suggested, might, by having projecting sides be made to answer this purpose. There is one danger to be apprehended, in thus, as it were, tying the carriages to the rails; so long as the machinery keeps sound, it insures all going right; but if any part breaks, there may arise as

great a shock from the wedging of the broken parts as from meeting a solid obstacle ; indeed small objects on the rails may induce, by this sort of wedging, a greater injury than might arise from being thrown off the rail.

Many of these cases, like most other known affairs, admit only of a choice of evils ; and experience can alone determine fully which gives the greater safety.

No means of locomotion for man has yet been devised in which fatal accidents do not occasionally occur ; even his own feet have betrayed him into falls destructive of life. The horse kills his thousands annually, from the saddle, and still more perhaps from the vehicles he gives motion to. The gallant sailing vessel is lost on the lee shore ; the steamer is not so caught, but as a full equivalent, adds the chance of being blown up to that of being drowned. Railways must never be expected to be exempt from this common condition of the power of moving, more especially if we consider what a quantity of it is condensed into so short a space of time : a man with his horse and gig travels thirty miles a day, but on the railroad he gets over this day's work in an hour : and if he spends his day on the railroad, he will only be at par, should he meet with ten or twelve times as many accidents as might occur to his gig that day. It is satisfactory, as regards the future prospects of railway conveyance, that the greater part of the accidents that have lately occurred on the various railroads have arisen from the want of proper precautions, rather than to matters inseparable from the nature of this mode of conveyance.

It was my intention when commencing this Essay, to take a cursory view of the moral as well as mechanical means of obviating danger on railways ; but the public attention is now quite sufficiently awake to the whole case ; and especially, to the former part of it. The late Railway Conference cannot fail to lead to the best results. I quite agree in its opinion, that any hasty legislation on the subject would be extremely dangerous to the public and the proprietors ; indeed the former must necessarily suffer with the latter, for unless the spirit of the speculation be kept brisk and lively, all attention would languish and a sleeping agency soon bring the thing into disuse. But though it would be unwise to legislate in the present crude state of our knowledge on this subject, it would be abundantly wise to appoint a Committee of Enquiry to take down all the best evidence impartially ; and to give it to the public aided by a well digested and luminous report. This could not fail to elicit such suggestions from talented and experienced individuals as would eventually lead to sound legislation.

I shall close these observations by describing a mechanical means of warning trains of the approach of danger, which, if properly carried out, will nearly ensure them from any collision with others. To do this, it is, however, necessary to make it a positive law, that the up trains shall always keep to one set of rails, and the down trains to the other.

Mr. Curtis has, I find, anticipated me in applying the tension of rods or wires to transmit signals from one station post to another at a considerable distance. I shall therefore leave it in his better hands,



excepting so far as respects its application to the case alluded to, which that gentleman has not noticed.

An ordinary train of thirty tons going at  $22\frac{1}{4}$  miles per hour, after the force of the engine is cut off, proceeds, according to the experiments of Mr. Gregory on the Croydon railway, about 380 yards before it stops; but when the steam was cut off from an assistant engine behind the train, and its break screwed down, the engine stopped in less than its length. If, therefore, the drags proposed be placed on all the carriages of a train, it would be stopped in a few yards.

Suppose that signal posts be placed at a mile distance from each other on each side of the railroad, the one for the up, the other for the down trains;\* let these posts be furnished with lamps for gas lights by night, and with red signals for both night and day work. By a contrivance which will be detailed for those who may chuse to wade through such matters, every train that comes up to one of these posts, causes its red signal to be hoisted, which continues up till the train proceeds a mile further, and has arrived at the next post, in passing which the signal on the *first* post is withdrawn; and thus, should an accident cause the train to stop, before it reaches the *second* post the signal for danger will be up in the face of the succeeding train, without trusting to fallible human attention.

For the purpose of obviating the possible want of attention in the conductor, more especially in the case of fogs, a *bell* should likewise be so arranged as to ring on the train passing any post showing the red signal; or, according to Mr. Rotch's plan, the steam whistle may be set in action. As soon as the conductor, by some of those means becomes aware of approaching danger, he must proceed slowly and cautiously to the point where the preceding train has stopped. The only danger that can occur with proper attention to these mechanical signals, is, when the stoppage, from accident, happens immediately after a train has passed its guardian signal post; because at night, or in a fog, the conductor of the following train might not see the signal in time to enable him to stop it completely; yet as it appears, from the experiments of Mr. Gregory, a proper application of drags, as previously noticed, will be sufficient to effect this in a few yards, the risk, is very slight; and even this risk may be still further diminished, if every train, as it undoubtedly ought to be, were furnished with an alarm bell, to be rung by one of the officials from the time of any accident, till all be right again.†

A round rod of iron a quarter of an inch thick, and one mile in length, will weigh about 850 lbs., and is qualified to exert a tension without injury, of more than 1000 lbs.: if supported on small pulleys or rollers, every six feet, the friction in moving it for a few inches, which is all that is required for the intended purpose, will

\* One set of posts in the middle might do for both.

† A hand bell of good size would be most likely to be ready, in the event of the engine being upset, and ought to be kept in some conspicuous place in addition to the fixed one.



amount to a mere trifle; any tension therefore within the limits of 1000 lbs. may thus be commanded between posts one mile asunder. Let A. Fig. 4, be a gas lamp, showing the ordinary white light, and B, a pane of transparent red glass of the full size of the side of the lamp, set in a frame which is connected with a sliding rod, passing down the hollow shaft of the column which supports the lamp: this frame, and part of the adjacent glass, is painted bright red, for a day signal, but is so masked by the shade C in front of it, that it cannot be seen till lifted up, so as to correspond in position with the plate of clear glass forming the side of the lamp which it then covers, and exhibits the red signal both by night and day. The rod supporting this red frame passes down below the lamp post, and the termination of it is furnished with a flat plate, which rests on the circular end of the beam D, which beam turns freely on an axis in its centre, so that when depressed at one end, the other is elevated, and by this means the rod and its signal are lifted when required. On this rod there is a projecting tooth which receives a catch by a weight or spring E, so that when the signal is hoisted, it cannot come down till this catch be liberated, when it instantly descends till the plate at the end again rests on the circular projecting part of the lifting beam to be ready for the next occasion. The opposite end of the beam is connected with an upright rod F, which at its lower end rests on a spring G, and has its upper end jointed into one of the two oblique moveable bars H, H. These bars when forcibly pressed down, can become horizontal; the ends being, in order to effect this purpose, jointed in connection with the railway bars K, K, Figs. 4, and 5, and their point of union connected by a bolt working in a groove of sufficient length to permit the free action of these bars, from an oblique to an horizontal position.

It is evident, from this construction, that, if a carriage passing along the rail, has a small projecting wheel so fixed as to roll over these bars at the level of their hinges, they must bring them gradually into a horizontal position, and thus compress the spring G, and by the beam D, elevate the signal B.

When the carriage has passed the beam D, the connected bars H H, return to their former position; but the catch connected with the weight E, retains the signal in its place until the carriage arrives at the next signal lamp, when, by communicating a strong tension to the mile of wire, passing over the pullies M M, the catch is liberated, and the signal falls behind its mask; thus showing that that mile of railway is clear for the next train. The pull which liberates the catch is communicated at the signal post in advance by an apparatus, similar to what is here shown, as connected with the one a mile in the rear.

From the top of an upright arm in the beam D proceeds a strong cord, passing over two pullies and under a third at N. When it has passed the third pulley it is made fast to the wire L, and thus connected with the signal-lamp in the rear; by this means the same movement which elevates the signal at this post, withdraws it at the other. This part of the apparatus is rendered more complicated in

Fig. 4.

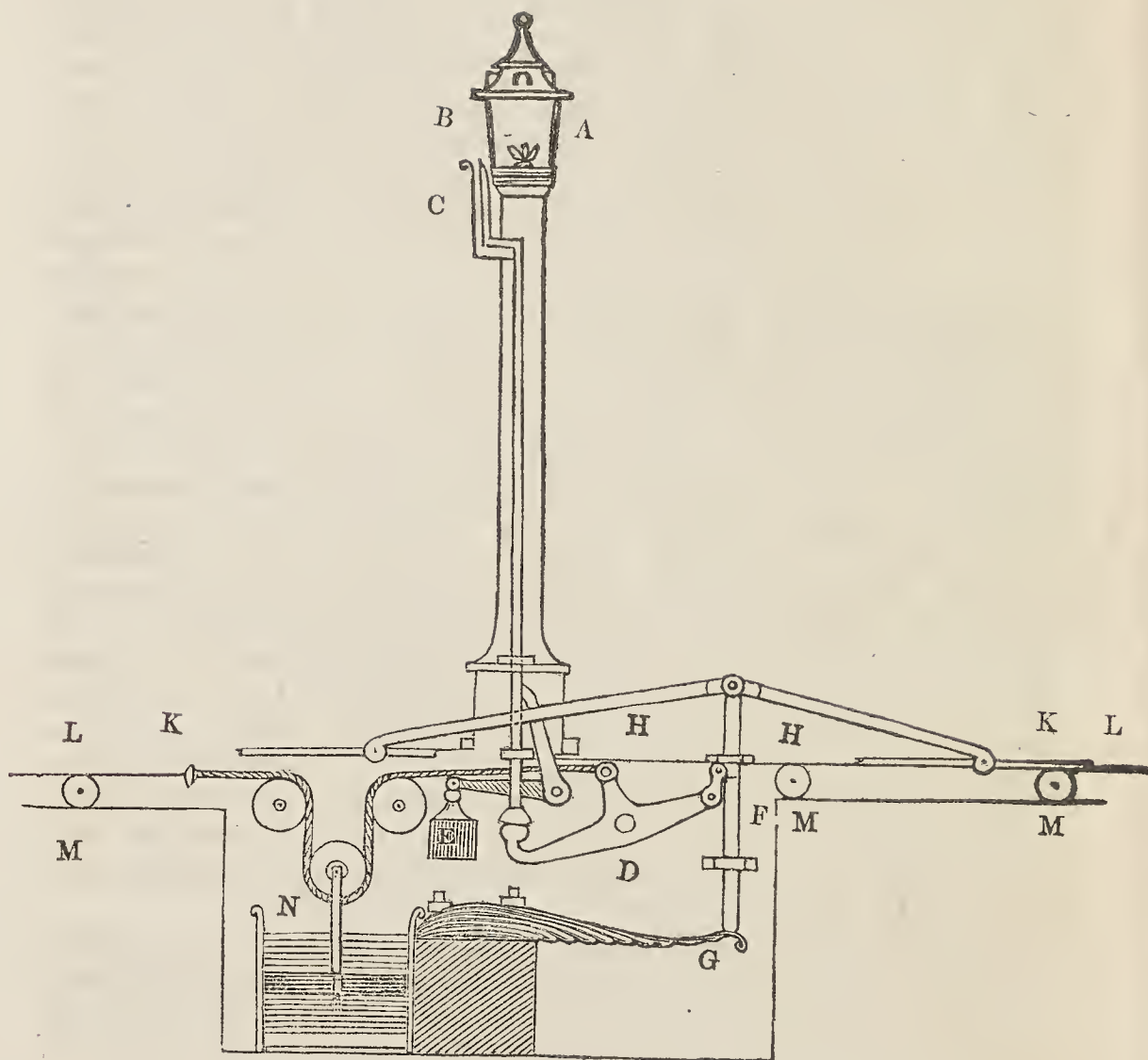
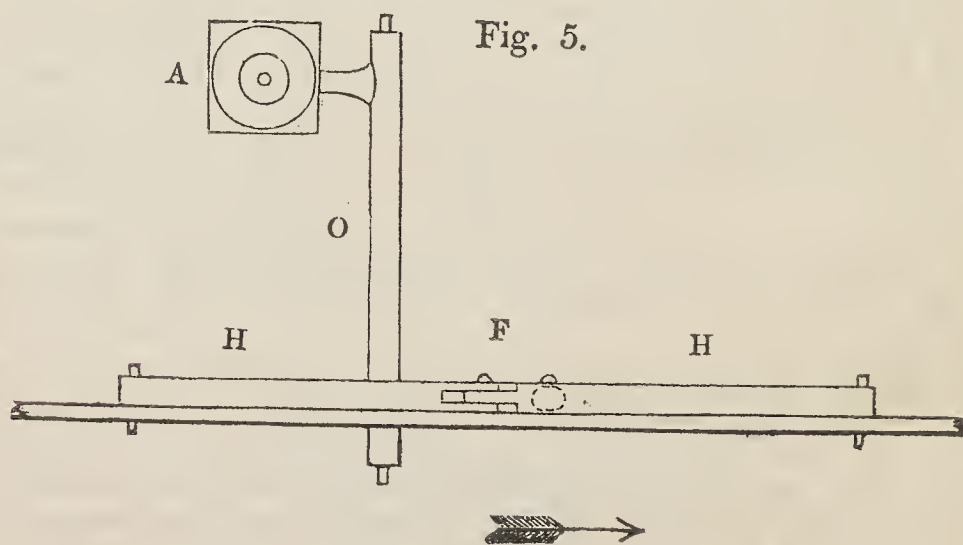


Fig. 5.





appearance by its being necessary to compensate for the expansion and contraction of a mile of wire, which, in this climate, may have a range of about 40 inches. The vessel at N is filled with tar, or any viscid fluid that does not readily freeze; the middle pulley is placed on the top of a piston-rod, the piston of which fits, though not quite so as to touch the cylinder holding the tar; by this arrangement the piston, which must be duly weighted to suit the purpose, but not to overpower the catch, slowly accommodates itself to the expansion or contraction of the wire; but powerfully resists, by atmospheric pressure, the sudden pull of the arm of the beam D, so as to transfer it to the distant signal, as required. Many other methods might be shown for producing these effects, which are in fact of the most ordinary class of mechanical movements: I have arranged these more to point out the facility with which so desirable an object may be accomplished, than as the best means of executing the work.

It is necessary further to remark that the position of the lamp A with respect to the rails, is shown on the ground plan fig. 5; hence, several of the arms shown in profile as contiguous in fig. 4, are not, as there represented, in the same plane, but are placed at the further extremity of a long axis, as seen at fig. 5, which does not affect the efficiency of their mutual action, as already described.

Although the machinery has here been confined to the size of an ordinary lamp, there is no reason why the whole of it, especially the signal part, may not be made of any required magnitude.

If a train pass a lamp when the signal is up, a bell attached to the post ought to be rung, or the steam whistle of the engine opened by some simple contrivance brought into gear or withdrawn by the movements of the rod supporting the signal, which any engineer will readily accomplish.

The mechanical arrangement of the switches and points, by which trains are turned off from one set of rails to another, is complete enough when properly applied; but the conductor of a train must wholly trust for that application to another—he has no means of perceiving whether all is right or not. This is a fault that ought to be rectified, which might readily be done by connecting the movement of the points, from an arm attached to them under ground, with some visible signal at the side of the road, so that the conductor may become fully aware how they are placed before he comes up to them.

Hitherto the means of safety for trains, as a whole, have been considered; but as the officers on whose conduct depends the security of all the rest, proceed with the engine in front, it may not be thought unfair to let these take a somewhat greater share in the danger, especially if in so doing we materially diminish that of all the others. The engine would pull the train with equal efficiency if a rope of fifty yards intervened; as is practically seen in the case of horses towing barges with a great length of rope;\* by this means if any accident stopped

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\* Without being aware of it, I find that I have, in suggesting this long rope, obtruded upon the patented invention of Mr. H. Bessemer. I am glad that this principle has been sufficiently matured to become the subject of a patent, and hope that it may be successfully applied for public use. The drags which might be



the engine there would be sufficient space for the train to be stopped by the drags before it came up with the engine. Should this arrangement be adopted it would be necessary to have an officer at the head of the train in addition to those with the engine, for the purpose of working the voluntary drags, if they may be so termed, and regulating the speed on inclined falls of the rail-road—but these must be so constructed as also to act mechanically on the occasion of the engine being stopped, and not trust to human attention on so momentary and usually unexpected a contingency. As these voluntary drags turn freely on an axis, suppose that whenever the train is at rest they are brought by a slight spring or weight just up to the point where their action would commence, by the wheels getting upon them, so that if the train were moved forward they would act. If the rope from the engine be made fast to a lever so connected with the spring which brings the drags into play that as long as the engine continues to pull, the action of the spring is overcome, they will not impede the progress of the train; but if the engine stops, the drags are instantly at work. The officer at the head of the train may make a voluntary use of these drags at any time, by means of a lever with which he intercepts the tug of the engine from bearing upon the springs—and he should have the command of a break for the purpose of regulating the speed. He may also be provided with a stop-bolt or catch, to prevent the drags acting when inconvenient.\*

I cannot conclude this essay upon some of the leading mechanical desiderata for promoting safety on rail-roads, without expressing an earnest hope that this noble, most useful, and delightful invention, which gives to man a so much wider scope of action, and must therefore, proportionately, accelerate his civilization and improvement, will obtain the most serious attention, and cautious support of an enlightened legislature, and that rail-road conveyance may thus soon be ripened into a security which at present is so lamentably wanting.

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applicable to such a lengthened pull, formed part of a plan designed by Mr. Frederic Worsley and myself two years ago, in which the engine was to be attached to the train by means of a lewis of a particular construction, and so arranged, that if the engines were thrown off the rails, it became disengaged from the trains, which the breaks would then immediately stop.

\* As it would not be convenient that every momentary variation in the tension of the engine should bring the drags to act, some given time must be allowed to intervene between the one ceasing and the other commencing to act, say that in which the train would proceed ten yards. This may be regulated to any extent, if no better means be devised, by making the springs draw up a small piston, working against atmospheric pressure (under oil which can only pass the piston at a given speed through an aperture properly regulated by a stop-cock) before they can bring the drags to work. One piston a foot in diameter and making a foot stroke, placed in the leading carriage, will be sufficient for the whole train; and it requires no nicety in its construction; hammered sheet iron even may be used for the cylinder in which it works.

My dear Sir, The Binder knows  
it seems left room for an  
other Essay, so may write  
one on what Sir George Rose  
calls Kollocuties or a fit  
conclusion to one of mine -

EL





























